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A risk assessment of potential Great Lakes aquatic invaders

Abigail Fusaro[1]
Emily Baker[2]
Whitney Conard[2]
Alisha Davidson[1]
Kyle Dettloff[3]
Jane Li[4]
Gabriela Núñez-Mir[5]
Rochelle Sturtevant[6]
Edward Rutherford[7]

[1]Wayne State University, 5047 Gullen Mall, Detroit, MI 48202
[2]University of Michigan, SNRE, 440 Church St., Ann Arbor, MI 4810
[3]Oregon State University, Corvallis, OR 97331
[4]Skidmore College, Saratoga Springs, NY 12866
[5]Worcester Polytechnic Institute, Worcester, MA 01609
[6]NOAA Sea Grant, 4840 S. State Rd., Ann Arbor, MI 48108
[7]NOAA Great Lakes Environmental Research Laboratory, 4840 S. State Rd., Ann Arbor, MI 48108

UNITED STATES
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Penny Pritzker
Secretary

NATIONAL OCEANIC AND
ATMOSPHERIC ADMINISTRATION

Dr. Kathryn D. Sullivan
Under Secretary for Oceans & Atmosphere
NOAA Administrator

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1. INTRODUCTION

Introduced species have the potential for both ecological and socioeconomic effects. Once established, these species can be nearly impossible to eradicate (Hobbs & Humphries 1995). In the few successful eradication efforts, the cost has been substantial (Simberloff 2003). Managing spread and controlling for impact are also costly (Leung et al. 2002). At least 31% nonindigenous species established in the Great Lakes have significant impacts (Sturtevant et al. 2014). The most economically and practically effective strategy is therefore to prevent species introduction in the first place (Lodge et al. 2006). As a means of prioritizing management efforts, risk assessment tools that consider vectors and pathways of introduction, species life history traits, habitat suitability, historical patterns of invasion, impacts realized in other invaded regions have become commonly implemented (Gordon et al. 2012, Keller et al. 2009). In order to accurately predict risk, a thorough understanding of these potentially introduced species is needed (Keller et al. 2007b, Springborn et al. 2011—but see Simberloff 2003). However, species and pathway information can also be scarce or diffuse (e.g., 95/156 species assessed as “not enough known” in USEPA 2008).

1.1 Aquatic Invasive Species in the Laurentian Great Lakes

The Laurentian Great Lakes is one of the most heavily invaded aquatic systems in the world with over 180 documented aquatic nonindigenous species, the peak invasion rate was estimated to be 2.8 species introduced per year (1990-1995) (GLRI Task Force 2010, Mills et al. 1993, Ricciardi 2006). Some of these nonindigenous species may become invasive (i.e. “those species whose introduction does or is likely to cause economic or environmental harm or harm to human health” (E.O. 13112, 1999) and threaten the ecological and/or socio-economic value of the Great Lakes. In contrast, some nonindigenous species are capable of contributing value to the Great Lakes. Pacific salmonids, for instance, are stocked annually by the millions and provide a major support for the Great Lakes’ multi-billion dollar fishery (Kocik and Jones 1999, Southwick Associates 2007, Talhelm 1985, USACE 2012, USFWS/GLFC 2010).

This study sought to identify the potential for introduction, establishment, and impact of 67 species identified in published literature as being highly likely to invade the Great Lakes basin. We developed tools that apply a consistent approach across all taxonomic groups and vectors in order to allow for comparison across these species, unlike previous studies. Our framework was comprised of three qualitative, question-driven assessments for which we relied on thorough Internet and literature searches, as well as expert judgment, to score and rank species’ introduction, establishment, and impact potentials. Scores were binned into categories of low, moderate, high, or unknown potential—the latter based on being unable to assess based on information availability. By ranking the potential for introduction via any of six major pathways; the potential for species to become established and overwinter; and the environmental impact, socio-economic impact, and beneficial effect of each species, this system provided a method of identifying and comparing impacts across taxa and type of impact. These assessments will inform ongoing work to map cumulative risk of invasion in the Great Lakes and guide prioritization by managers in their monitoring and response programs.

1.2 Project Background

In cooperation with USGS, NOAA GLERL has been tracking nonindigenous aquatic species in the Great Lakes system since 2003 and serving that information through the GLANSIS database (http://www.glerl.noaa.gov/res/Programs/glansis/glansis.html). Information in the database includes an overview of the species life history, ecology, and invasion history as well as maps of current distribution, comprehensive impact assessment and overview of management options. With funding from the Great Lakes Restoration Initiative, beginning in 2011, we were able to begin adding information on species that were not yet established in the Great Lakes, but had been assessed in the peer-reviewed scientific literature as posing a risk of invasion. We aimed to provide a similar comprehensive risk assessment looking in detail at the risks for introduction, establishment and impact along with information on life history, ecology, invasion history, and management options to help guide early detection and rapid response efforts.

1.3 Review of Invasive Species Risk Assessments

Biological invasion risk assessment continues to be a young field, with a variety of approaches, scope, content, and required elements (reviewed in Verbrugge et al. 2010, Dahlstrom et al. 2011). Risk assessment can have different endpoints, with species' introduction commonly chosen (Andersen et al. 2004); they are less consistent in their treatment of establishment (colonization and spread) and consequence (impact). However, given the number of failed introductions, an understanding of establishment potential remains important. Impact is necessary to give a full understanding of risk (which includes both the probability of an event occurring and the severity of that event). Understanding impact is also a key element to species' management, as an understanding of small versus large effects allows better prioritization of management efforts (Parker et al. 1999).

Structurally, invasion risk may be evaluated quantitatively (with numerical probabilities or descriptors), qualitatively (with categorical descriptors), semi-quantitatively (by representing quantitative data with categorical descriptors), or using rule sets or decision trees with arbitrary risk thresholds (in which a single criterion determines the outcome) (Hayes 1997, Keller et al. 2007b). Issues of objectivity and consistency in professional opinions can arise in qualitative assessments (Burgman et al. 1999, but see use of structured expert judgment in Wittmann et al. 2014). As such, quantitative approaches are often favored despite their sensitivity to weighting schemes (e.g., Pheloung et al. 1999) and dependence on complete data sets, which rarely occur (Campbell 2009). Thus, there is a tradeoff between qualitative approaches (often easier to complete, albeit with potentially less supportable results) and quantitative approaches (may be impossible to complete given available data, but are viewed as preferable).

Extensive work has been conducted on pathway- (e.g., USACE 2011), vector- (e.g., Colautti et al. 2003), and taxon-specific (e.g., Mendoza-Alfaro et al. 2009) assessments, particularly relating to ballast introductions (e.g., Grigorovich et al. 2003), but very few of these efforts have considered live trade (but see Keller and Lodge 2007; Marson et al. 2009; Rixon et al. 2005) or recreational boating (e.g., Rothlisburger et al. 2010). Moreover, multi-vector assessments are rare and have been focused on ecological and economic impacts of established Great Lakes AIS (e.g., Keller et al. 2009) or on vector/pathway analysis alone (e.g., Kelly 2007) rather than forecasting the likelihood of introduction, spread, or consequence for new invaders to the system. Where assessments of existing and high risk AIS do exist, there has been a further scarcity of information, resulting in the inability to predict likelihood and consequence for those species (e.g., NOAA 2012, 'current research is inadequate to support proper assessment;' USEPA 2008, 'NEK' not enough known).

2. METHODS

2.1 Overview of Risk Assessment Structure

We employed an assessment framework for aquatic nonindigenous species that addressed several of the limitations discussed above. In particular, our semi-quantitative framework aimed to compare multiple taxa and pathways, to consider the full invasion process from introduction to impact, account for the breadth of possible impacts, and gauge uncertainty with each assessment. This was targeted at providing information needed to develop comprehensive policies that are not limited to isolated groups of organisms or pathways of introduction. It was also designed to allow managers to make more informed decisions about which pathways to monitor with greater effort, relative to threats organisms in those pathways may pose. It is hoped that managers will be able to adopt precautions with respect to their tolerance of risk concerning the likelihood of species establishment and impact. Additionally, our framework was constructed to be adaptable and easily amendable as more information about species or pathways becomes available.

This invasive species assessment framework consisted of three qualitative, question-driven assessments for which we relied on thorough Internet and literature searches, as well as expert judgment, to score and rank species' potential for introduction, establishment, and impact. These assessment tools were modeled after the United Kingdom Non-Native Organism Risk Assessment scheme (Baker et al. 2008) with adaptations for freshwater species. This is a question-based, semiquantitative designed to work across diverse taxa based on 'readily available' information specific to the receiving system and about the particular species in a logical framework following established risk analysis procedures. This model was selected because it was one of the most comprehensive and straightforward models that could be applied broadly across taxa as well as being particularly transparent in that every individual score is justified with a written comment. This framework allows for the addition of additional assessments (questions or entire sections) should releavant information (e.g., climate or habitat suitability) become available either at the cross-taxa scale or for particular species. The three assessments of our analysis were Introduction, Establishment and Impact.

We first considered a species presence and likelihood of delivery via each of six major vectors. Based on ecological and habitat characteristics, we then assessed its potential to become established and overwinter. Lastly, we predicted its potential for environmental and socio-economic impacts, and beneficial effects. For each sub-assessment, we binned semi-quantitative scores into categories of low, moderate, high, or unknown—the latter based on being unable to assess based on information availability. By ranking these relative scores, this system provided a method of identifying and comparing impacts across taxa and type of impact.

The Potential for Introduction assessment sought to identify all possible vectors of introduction and a species' proximity (or ease of introduction) to pathways into the Great Lakes. This assessment considers paired questions for each of six vectors. The Potential for Establishment assessment consisted of 18 questions evaluating characteristics of potential invaders, such as biological and ecological attributes, environmental compatibility, propagule pressure, and history of invasion and spread. The Potential for Impact assessment separately considers the harmful environmental and socioeconomic impacts, as well as beneficial effects of these species' invasions elsewhere around the world, with six questions for each impact type.

2.2 Potential for Introduction

Species introduction assessment criteria and relative levels of introduction likelihood within each vector were developed based on a literature review of vectors of aquatic species introduction. It incorporated vectors identified by Kelly (2007, modified from Holeck et al. 2004) in a Great Lakes vector assignment protocol. Vectors not present in that protocol were obtained from the United States Geological Survey's (USGS) Nonindigenous Aquatic Species (NAS) database's standardized list of vectors (USGS 2011). These include the following vectors: canals and waterways (dispersal), trade of live organisms (stocking/planting/escape from recreational culture, release, escape from commercial culture), activities of recreational and resource users (hitchhiking/fouling), and commercial shipping (transoceanic shipping). In this assessment, we separated live trade into three vectors according to the distinct nature of practices and regulations surrounding each (e.g., water gardening practices vs. commercial culture). Assessment criteria and relative levels of introduction likelihood within each vector are based upon the results of a literature review. The tool was structured according to the United Kingdom Non-Native Organism Risk Assessment scheme (Baker et al. 2008) with adaptations for the Great Lakes.

The potential for introduction assessment took into account a "proximity" proxy for each pathway using a suite of 12 paired questions (two per vector). The first question in a pair considered potential pathways for introduction, assigning a score from 0 to 100—usually 100 for being in a particular pathway and 0 for not—while the second question evaluated the likelihood of a species to enter the Great Lakes through that pathway, using a multiplicative factor from 0 to 1. If a question could not be answered based on available data, an "unknown" option was available.

- Dispersal – (a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin? (b) What is the proximity of this species to the Great Lakes basin?
- Hitchhiking/Fouling - (a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin? (b) What is the proximity of this species to the Great Lakes basin?
- Unauthorized intentional release – (a) Is this species sold at aquarium/pet/garden stores ("brick & mortar" or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin? (b) How easily is this species obtained within the Great Lakes region (states/provinces)?
- Stocking/Planting/Escape from Recreational Culture – (a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region? (b) What is the nature and proximity of this activity to the Great Lakes basin?
- Escape from Commercial Culture – (a) Is this species known to be commercially cultured in or transported through the Great Lakes region? (b) What is the nature and proximity of this activity to the Great Lakes basin?
- Shipping – (a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)? (b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

A score sheet was kept for tallying the results for each species.

Vector Potential Scorecard				
Vector	**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind	**100**	x 1	**100**	High
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.	**100**	x 1	**100**	High
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)	**100**	x 1	**100**	High
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)	**100**	x 1	**100**	High
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)	**100**	x 1	**100**	High
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling	**100**	x 1	**100**	High
Total Unknowns (U)	**0**	**Confidence Level**	High	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High
1-2	Moderate
3-5	Low
>5	Very low

Figure 1: Score sheet for probability of introduction assessment. Example scored to maximum.

Overall probability for introduction per vector (High, Moderate, Low) was determined by the adjusted point score for the species in that vector. Thresholds for introduction probability were set such that species in the closest proximity to the Great Lakes (relative to the pathway of introduction) would be evaluated as having High probability, those at intermediate distances would be evaluated as having

Moderate probability, and those either not in the pathway or at the furthest distance would be evaluated as having Low probability. Summary tables provide scores summed across vectors – e.g., a species which scores 75 (moderate) on each of two vectors has a total score of 125 and was considered to have a high overall probability of introduction. Although summation in this fashion led to a possible maximum score of 600, this was possible only if a species were to be present and in high proximity in all six vectors simultaneously. Scores exceeding 100 were actually quite rare. The highest score actually produced in our species set was 450 (for *Eichhornia crassipes* which is present in 5 of the 6 vectors).

Assessment confidence levels were assigned for each species assessment by taking into consideration the total number of questions which could not be evaluated based on available scientific literature. Confidence is deemed to be High if there are no unknowns, Moderate if there were unknowns for one-third or fewer of the vectors, Low if there were unknowns for more than one third of the vectors, and Very Low if there were unknowns for all but one vector. Overall for the 67 species assessed, only 19 of the 804 questions (2%) could not be answered. Confidence was high in the assessments for most species with no questions unanswered. Only one species (*Egeria densa*) was assessed with low confidence, and only 10 (15%) at moderate confidence (one question unanswered).

2.3 Potential for Establishment

The establishment assessment was developed based on a literature review of variables that aid or detract from an invader's establishment success and spread potential, as relevant to the Great Lakes. Contributing variables were broadly grouped into a total of 18 questions within four categories: invasive biological/ecological attributes (environmental tolerance, overwintering, diet, competitive ability, fecundity, reproductive mode), environmental compatibility (climate, water quality, habitat, climate change, food availability, interspecific dependence/facilitation/inhibition), propagule pressure (inoculum size, frequency), and history of invasion and spread (extent, rate of spread, prevention). Again, this assessment tool was modeled after the United Kingdom Non-Native Organism Risk Assessment scheme (Baker et al. 2008) and adapted for the Great Lakes. While important to successful establishment/spread, initially proposed questions concerning genetic diversity of potential source population, genetic and phenotypic variation, and likelihood of introduction during time of year appropriate for establishment were deemed unlikely to be able to answer a priori for most species; these questions were therefore removed from the assessment.

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

- How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described? (0-9)
- How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)? (0-9)
- If this species is a heterotroph, how would the flexibility of its diet be described? (0-9)
- How likely is this species to outcompete species in the Great Lakes for available resources? (0-9)
- How would the fecundity of this species be described relative to other species in the same taxonomic class? (0-9)
- How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self-fertilization, vegetative fragmentation)? (0-9)

ENVIRONMENTAL COMPATIBILITY

- How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region? (0-9)

- How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes? (0-9)
- How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)? (0-9)
- How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)? (0-9)
- How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)? (0-9)
- Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)? (0-9 OR -80% if critical species not present in GL and not likely to be introduced)
- How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes? (0-9)
- How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species? (zero to -80%)

  PROPAGULE PRESSURE
- On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?) (0-9)

  HISTORY OF INVASION AND SPREAD
- How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities? (0-9)
- How rapidly has this species spread by natural means or by human activities once introduced to other locations? (0-9)
- Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species? (zero to -90%)

Overall species' establishment potential was determined by its total point score. Answers to three of the 18 questions could lead to an overall percentage reduction in a species' score. Such adjustments were warranted when a variable would counter or prevent the species' establishment; these included lack of a critical species (e.g., host), presence of a natural enemy, and implementation of control measures. Species could score a High establishment potential if at least three-quarters of the questions were scored as 9s or a Moderate establishment potential if more than half of the questions were scored as 6s (or were evenly split with equivalent numbers of 3s and 9s); otherwise the species was ranked as having a Low establishment potential.

Establishment Potential Scorecard				
Points	**Probability for Establishment**	A. Total Points (pre-adjustment)		144
>100	High	**Adjustments**		
		B. Critical species	A*(1- 0%)	144

51-99	Moderate	C. Natural enemy	B*(1- 0%)	144
		Control measures	C*(1- 0%)	144
0-50	Low	**Potential for Establishment**		High
# of questions answered as "unable to determine"	**Confidence Level**			
0-1	High	Total # of questions unknown		0
2-5	Moderate			
6-9	Low	Confidence Level		High
>9	Very low			

Figure 2: Score sheet for the probability for establishment. Example scored to maximum.

The assessment did not weight all 4 categories equally; biological attributes were assessed based on 6 questions with a maximum of 54 points, environmental compatibility based on 8 questions with a maximum of 63 points, propagule pressure based on 1 question worth 9 points and history of invasion and spread based on 3 questions with a maximum of 18 points.

Confidence levels were assigned by taking into consideration the number of questions that could not be evaluated based on available scientific literature. Confidence in the assessment for each species was deemed High if one or fewer questions could not be answered, Moderate if fewer than one third of the questions could not be answered, Low if more than one third of the questions could not be answered, and Very Low if more than half of the questions could not be answered. Among the 67 species assessed, 97 of the 1206 questions (8%) could not be answered. Four invertebrate species assessed at low confidence (*Ectinosoma abrau*, *Paraleptastacus spinicaudus triseta, Sinelobus stanfordi, and Leyogonimus polyoon*) accounted for 28 of these unanswered questions. Lack of knowledge of propagule pressure accounted for 39 of the unanswered questions.

2.4 Potential for Impact

The potential for impact assessment was modeled after a tool used to assess the realized consequences of nonindigenous species already established in the Great Lakes (Sturtevant et al. 2014). It examines potential adverse environmental and socioeconomic impacts (including human health), as well as potential beneficial effects.

Modifications to Organism Impact Assessment used for established species included:

- Addition of "Potential" impact
- Addition of impact consideration "from any non-native region"
- Revised and standardized use of "added pressure to threatened/endangered species" for high impact categories in biological/environmental effects in order to capture that any adverse effects against endangered species are significant/high impact, while a more extreme effect against a native species would be needed to consider it as being significant/high.
- Deletion of "AND/OR" significant effects " in past invasions outside of the Great Lakes" clauses because we are only considering invasions outside of the Great Lakes

- Revised qualitative statements to “has the *potential* for __ impact if introduced to the Great Lakes”

This assessment is divided into sets of six questions within each these three impact categories: environmental impact (toxicity/facilitation of parasitism or viral/bacterial infections, competition, trophic alteration, genetic effects, degradation of water quality, degradation of physical habitat); socioeconomic impact (human health, infrastructural damage, degradation of water quality related to human use, harm to economic sectors, harm to recreational potential, diminishment of aesthetic quality); and beneficial effect (use for biocontrol, commercial value, recreational value, medicinal/scientific value, improvement to water quality, other ecological services).

POTENTIAL ENVIRONMENTAL IMPACT

- Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?
- Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?
- Does it alter predator-prey relationships?
- Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?
- Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?
- Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

POTENTIAL SOCIO-ECONOMIC IMPACT

- Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?
- Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?
- Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?
- Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?
- Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?
- Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

POTENTIAL BENEFICIAL EFFECT

- Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?
- Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?
- Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?
- Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?
- Does the species remove toxins or pollutants from the water or otherwise increase water quality?
- Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Scores for each criterion (0, 1, or 6) were summed per impact category (36 point maximum) and converted to an overall impact ranking using an established scoring table that accounts for level of uncertainty in the assessment (i.e. number of unknowns, see Figure 3).

Environmental Impact Total	**36**
Total Unknowns (U)	**0**

Socio-Economic Impact Total	**36**
Total Unknowns (U)	**0**

Beneficial Effect Total	**36**
Total Unknowns (U)	**0**

Scoring for EACH Subassessment		
Score	# U	**Impact**
>5	Any	**High**
2-5	Any	Moderate
0	0-1	Low
1	0	
0	≥2	Unknown
1	≥1	

Figure 3: Score sheet of impact potential results. Sample scored as maximum impact.

Rather than employing a 'confidence' metric as with the previous two assessments, the assessment of potential impact followed the protocol of our earlier assessment of impact for established species in folding this into the risk score such that any subassessment with a score of 0 but more than two unanswered questions is itself considered 'unknown' as is any subassessment with a score of 1 and more than one unknown – effectively no confidence in the result. Because the effect of unanswered questions may only result in a lower score (unanswered questions can only increase score), those subassessments scoring moderate to high with significant unknowns should be considered 'at least' moderate or 'at least' high. Across the sixty-seven species (1206 total questions), a total of 189 (16%) were unable to be answered based on literature review. Environmental impact was assessed as unknown for 26 of the 67 species (39%), socioeconomic impact was assessed as unknown for five species (7%) and the benefits were assessed as unknown for one species (1.5%). These percentages are comparable to the state of knowledge for established species – fully 49% of the established species scored with unknown environmental impacts, 7% with unknown socioeconomic impacts and 8% with unknown benefits (Sturtevant 2014).

2.5 Application to Great Lakes Watchlist Species

We applied our assessment framework to 67 species identified as fitting the following criteria:

Geographic criterion: Lives in a known donor region (e.g., rivers adjacent to Great Lakes, inland lakes in the Great Lakes region, western Europe, the Ponto-Caspian region) or in a zone with high specialization, species pool, or climate conditions that match the Great Lakes.

Aquatic criterion: USDA wetland indicator status was used as a guideline for determining whether wetland plants should be included in the list obligate (OBL), facultative wetland (FACW), and facultative (FAC) plants were included in this list as aquatic; facultative upland (FACU) and upland (UPL) plants were not. Waterfowl, reptiles, and mammals spending significant time in and dependent on the water were not included.

Established criterion: **NOT** already established in the Great Lakes, but assessed as 'likely' to become so by identification in one or more peer-reviewed scientific publications as having high probability for survival, establishment, and/or spread if introduced to the Great Lakes OR meeting at least three of the following five criteria:

1. A transport vector currently exists that could move the species into the Great Lakes
2. The species is likely to tolerate/survive transport (including in resting stages) in the identified vector
3. The species has a probability of being introduced multiple times or in large numbers
4. The species is likely to be able to successfully reproduce in the Great Lakes
5. The species has been known to invade other areas

The potential warming of the Great Lakes due to climate change was an important factor to consider in light of potential future invaders. The GLANSIS watchlist includes a few species for which predicted increases in water temperature have led to explicit remarks concerning future invasion probability. Otherwise, species which may be introduced but are not likely to overwinter given the current temperature regime were excluded from this list of high probability invaders.

By ranking each species' potential 1) for introduction via any of six major vectors; 2) to become established and overwinter; and 3) for environmental impact, socio-economic impact, and beneficial effect, this framework provided a comprehensive and consistent method of identifying and comparing impacts across taxonomic groups, pathways, and impact categories. It was our intent that this multi-taxa, multi-vector approach will guide prioritization by managers in monitoring and response programs. The draft species list was circulated among regional and taxonomic experts to identify species which should be added or removed from the list based on more recent information and/or expert opinion.

After species selection, we completed the introduction, establishment, and impact assessment components for each species. We first considered a species' presence in and likelihood of delivery via each of six major vectors. Based on ecological and habitat characteristics, we then assessed its potential to become established and overwinter. Lastly, we predicted its potential for environmental and socio-economic impacts, and beneficial effects. The assessments were completed using an exhaustive literature review that included online species registries, aquatic invasive species databases, major bibliographic databases, peer-reviewed literature, published state and federal agency reports, reliable Internet sources on a variety of search terms, librarian services, expert consultation, and best professional judgment. We summarized our justification for each question's score and documented the information's source. Review was deemed sufficient after such searches exhausted novel sources of information. We sent completed assessments for expert review, with the instructions to evaluate its accuracy and supplement with additional information, if needed.

The 67 species assessed include 27 fishes, 32 invertebrates and 8 plants. As the initial list was based on the peer-reviewed literature, the composition of taxa in this list may reflect biases of the studies rather than a true reflection of the types of taxa likely to invade. For example, no studies were found which assessed the potential for aquatic insects to invade the Great Lakes.

We compared species' raw assessment scores and semi-quantitative ranking for introduction, establishment, and impact to determine trends in predicted invasiveness. In particular, we considered taxa, geographic origins, vectors, Great Lakes establishment, and impacts.

3. RESULTS

3.1 Framework

The framework development yielded three separate semi-quantitative, question-driven assessment components for a species' potential introduction (six pairs of questions), establishment (18 questions total), and impact (six questions for each of three broad categories). The final structure of each assessment component, based on the considerations described in the Methods above, is summarized below.

Potential for Introduction

Vectors in the introduction assessment component included 1) canals and waterways (dispersal), 2) activities of recreational and resource users (hitchhiking/fouling), 3) unauthorized deliberate release, 4) stocking/planting/escape from recreational culture, 5) escape from commercial culture and 6) commercial shipping (transoceanic shipping).

In general, available data was sufficient to complete the assessment. Only 19 questions in total could not be answered in the entire assessment (an average of 0.28 questions per species) giving a high overall confidence level. Available data for plants was somewhat lower quality – over half of the missed questions were in regard to plant species (averaging 1.25 questions per plant species).

Table 1: Probability of introduction of fishes to the Great Lakes basin.

Species	Dispersal	Hitchhiking or Fouling	Unauthorized Release	Stocking, Planting, or Escape Recreation al Culture	Escape Commercial Culture	Transoceanic Shipping	**Overall**	Unknowns and Confidence
Alburnus alburnus	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	40 Moderate	**40** **Moderate**	0 High

Atherina boyeri	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	40 Moderate	**40** **Moderate**	0 High
Babko gymnotrachelus	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	40 Moderate	**40** **Moderate**	0 High
Benthophilus stellatus	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	8 Low	**8** **Low**	0 High
Carassius carassius	0 Unlikely	0 Unlikely	10 Low	0 Unlikely	0 Unlikely	0 Unlikely	**10** **Low**	0 High
Channa argus	25 Low	0 Unlikely	50 Moderate	Unknown	0 Unlikely	0 Unlikely	**75** **Moderate**	1 Moderate
Clupeonella cultriventris	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	8 Low	**8** **Low**	0 High
Cottus gobio	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	40 Moderate	**40** **Moderate**	0 High
Ctenopharyngodon idella	100 High	0 Unlikely	50 Moderate	75 Moderate	25 Low	0 Unlikely	**250** **High**	0 High
Cyprinella whipplei	75 Moderate	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	**75** **Moderate**	0 High
Hypophthalmichthys molitrix	75 Moderate	0 Unlikely	50 Moderate	0 Unlikely	50 Moderate	0 Unlikely	**175** **High**	0 High
Hypophthalmichthys nobilis	75 Moderate	0 Unlikely	50 Moderate	25 Low	50 Moderate	0 Unlikely	**200** **High**	0 High
Ictalurus furcatus	25 Low	0 Low	10 Low	100 High	0 Low	0 Low	**135** **High**	0 High
Knipowitschia caucasica	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	40 Moderate	**40** **Moderate**	0 High
Leuciscus idus	Unknown	0 Unlikely	100 High	100 High	0 Unlikely	0 Unlikely	**200** **High**	2 Moderate

Leuciscus leuciscus	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	40 Moderate	**40** **Moderate**	0 High
Neogobius fluviatilis	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	40 Moderate	**40** **Moderate**	0 High
Oncorhynchus keta	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	**0** **Unlikely**	0 High
Osmerus eperlanus	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	40 Moderate	**40** **Moderate**	0 High
Perca fluviatilis	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	40 Moderate	**40** **Moderate**	0 High
Perccottus glenii	0 Unlikely	0 Unlikely	10 Low	0 Unlikely	0 Unlikely	40 Moderate	**50** **Moderate**	0 High
Phoxinus phoxinus	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	40 Moderate	**40** **Moderate**	0 High
Pseudorasbora parva	0 Unlikely	10 Low	Unknown	0 Unlikely	0 Unlikely	0 Unlikely	**10** **Low**	2 Moderate
Rutilus rutilus	0 Unlikely	0 Unlikely	10 Low	0 Unlikely	0 Unlikely	80 Moderate	**90** **High**	0 High
Sander lucioperca	25 Low	10 Low	0 Unlikely	Unknown	0 Unlikely	0 Unlikely	**35** **Low**	1 Moderate
Silurus glanis	0 Unlikely	0 Unlikely	Unknown	0 Unlikely	0 Unlikely	0 Unlikely	**0** **Unlikely**	2 Moderate
Syngnathus abaster	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	50 Moderate	**50** **Moderate**	0 High

Table 2: Probability of introduction for invertebrates to the Great Lakes basin.

Species	Dispersal	Hitchhiking or Fouling	Unauthorized Release	Stocking, Planting, or Escape Recreation al Culture	Escape Commercial Culture	Transoceanic Shipping	**Overall**	Unknowns and Confidence
Limnoperna fortunei	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	8 Low	**8** **Low**	0 High
Monodacna colorata	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	40 Moderate	**40** **Moderate**	0 High
Fredericella sultana	0 Unlikely	10 Low	0 Unlikely	0 Unlikely	0 Unlikely	100 High	**110** **High**	0 High
Apocorophium lacustre	50 Moderate	50 Moderate	0 Unlikely	0 Unlikely	0 Unlikely	50 Moderate	**150** **High**	0 High
Chelicorophium curvispinum	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	40 Moderate	**40** **Moderate**	0 High
Dikerogammarus haemobaphes	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	40 Moderate	**40** **Moderate**	0 High
Dikerogammarus villosus	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	40 Moderate	**40** **Moderate**	0 High
Echinogammarus warpachowskyi	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	40 Moderate	**40** **Moderate**	0 High
Obesogammarus crassus	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	40 Moderate	**40** **Moderate**	0 High
Obesogammarus obesus	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	10 Low	**10** **Low**	0 High

Pontogammarus robustoides	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	40 Moderate	**40** **Moderate**	0 High
Cornigerius maeoticus maeoticus	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	40 Moderate	**40** **Moderate**	0 High
Daphnia cristata	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	80 High	**80** **High**	0 High
Podonevadne trigona ovum	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	8 Low	**8** **Low**	0 High
Calanipeda aquaedulis	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	40 Moderate	**40** **Moderate**	0 High
Cyclops kolensis	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	40 Moderate	**40** **Moderate**	0 High
Ectinosoma abrau	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	8 Low	**8** **Low**	0 High
Heterocope appendiculata	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	40 Moderate	**40** **Moderate**	0 High
Heterocope caspia	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	40 Moderate	**40** **Moderate**	0 High
Paraleptastacus spinicaudus triseta	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	40 Moderate	**40** **Moderate**	0 High
Limnomysis benedeni	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	40 Moderate	**40** **Moderate**	0 High
Paramysis (Mesomysis) intermedia	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	40 Moderate	**40** **Moderate**	0 High
Paramysis (Metamysis) ullskyi	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	40 Moderate	**40** **Moderate**	0 High
Paramysis (Serrapalpisis) lacustris	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	40 Moderate	**40** **Moderate**	0 High

Cherax destructor	0 Unlikely	0 Unlikely	50 Moderate	0 Unlikely	0 Unlikely	0 Unlikely	**50** **Moderate**	0 High
Rhithropanopeus harrisii	0 Unlikely	10 Low	0 Unlikely	0 Unlikely	0 Unlikely	50 Moderate	**60** **Moderate**	0 High
Sinelobus stanfordi	0 Unlikely	10 Low	0 Unlikely	0 Unlikely	0 Unlikely	50 Moderate	**60** **Moderate**	0 High
Leyogonimus polyoon	0 Unlikely	50 Moderate	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	**50** **Moderate**	1 Moderate
Hypania invalida	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	40 Moderate	**40** **Moderate**	0 High
Brachionus leydigii	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	80 High	**80** **High**	0 High
Filinia cornuta	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	80 High	**80** **High**	0 High
Filinia passa	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	0 Unlikely	80 High	**80** **High**	0 High

Table 3: Probability of introduction of plants to the Great Lakes basin.

Species	Dispersal	Hitchhiking or Fouling	Unauthorized Release	Stocking, Planting, or Escape Recreation al Culture	Escape Commercial Culture	Transoceanic Shipping	**Overall**	Unknowns and Confidence
Crassula helmsii	0 Unlikely	0 Unlikely	Unknown	0 Unlikely	0 Unlikely	0 Unlikely	**0** **Unlikely**	2 Moderate
Egeria densa	Unknown	50 Moderate	100 High	25 Low	Unknown	0 Unlikely	**175** **High**	3 Low
Eichhornia crassipes	100 High	100 High	100 High	75 Moderate	75 Moderate	0 Unlikely	**450** **High**	0 High

Hydrilla verticillata	100 High	100 High	10 Low	Unknown	Unknown	0 Unlikely	**300** **High**	2 Moderate
Hygrophila polysperma	0 Unlikely	10 Low	50 Moderate	0 Unlikely	0 Unlikely	0 Unlikely	**60** **Moderate**	0 High
Myriophyllum aquaticum	100 High	100 High	100 High	75 Moderate	Unknown	0 Unlikely	**375** **High**	1 Moderate
Pistia stratiotes	100 High	100 High	100 High	100 High	Unknown	0 Unlikely	**400** **High**	2 Moderate
Stratiotes aloides	100 High	100 High	10 Low	100 High	0 Unlikely	0 Unlikely	**310** **High**	0 High

Of the assessed species, two fishes (*Oncorhynchus keta* and *Silurus glanis*) and one plant (*Crassula helmsii*) were found unlikely to be introduced to the Great Lakes. Six fishes (*Ctenopharyngodon idella, Hypopthalmichthys molitrix, Hypopthalmichthys nobilis, Ictalurus furcatus, Leuciscus idus, Rutilus rutilus*), and six invertebrates *(Fredericella sultana, Apocorophium lacustre, Daphnia cristata, Brachionus leydigii, Filinia cornuta, Filinia passa*) and six plants (*Egeria densa, Eichhornia crassipes, Hydrilla verticillata, Myriophyllum aquaticum, Pistia stratiotes, Stratiotes aloides*) were found to be highly likely to be introduced to the Great Lakes. Of these, the three rotifer species and the *Daphnia* were considered a risk solely due to the ballast water vector while all the other high risk species were a risk in multiple vectors.

Thirty-five species of fishes and invertebrates (but no plants) were found to be a low to moderate risk due solely to the ballast water vector. The high prevalence of ballast-mediated invaders on this list (67% of the species listed attribute some risk due to ballast) likely reflects the large number of studies that have been conducted with respect to potential ballast-mediated invasion. Changes in regulation of ballast water for the Great Lakes region over the past 20 years may be responsible for our lower assessment of the risk of these species (with regard to introduction) relative to the orginal assessments in the peer-reviewed literature which led to their selection for inclusion in our analysis.

Species with a high potential for introduction originated from each of the included geographic regions, including all of the species from South America (see Figure 4). All vectors except 'escape from commercial culture' were evenly represented among those with a high potential for introduction, but the shipping vector was disproportionally responsible (50%) for the species with significant (high + moderate) potential for introduction (see Figure 5).

Of the species assessed, fishes were present in all vectors with at least some potential for introduction, while plants were present in all except for the shipping vector. Nine fishes (33%) were present in more than one vector, with the ide (*Leuciscus leuciscus*) having a high potential of introduction through both unauthorized intentional release and stocking/planting/escape from recreational culture. The bulk of crustaceans (83%) were assessed as having a high or moderate potential to be introduced via shipping. Seven plants (88%) were present in multiple vectors; this included water hyacinth (*Eichhornia crassipes*), which was present in all except the shipping vector. Water lettuce (*Pistia stratiotes*) was ranked as having a high potential for introduction in four vectors (dispersal, hitchhiking/fouling, unauthorized intentional release, and stocking/planting/escape from recreational culture).

Considering the highest level of introduction potential for taxa across all vectors, high introduction potential was most prevalent among rotifers 3 of 3, bryozoans 1 of 1, and plants 6 of 8. Fishes 17 of 27 (63%), annelids 1 of 1, platyhelminthes 1 of 1, and crustaceans 20 of 24 (83%) most often ranked as having a moderate introduction potential. Mollusks (n=2) were evenly split between moderate and low introduction potential. Only three of the 67 species assessed (4%) were found unlikely to be introduced to the Great Lakes via any vector.

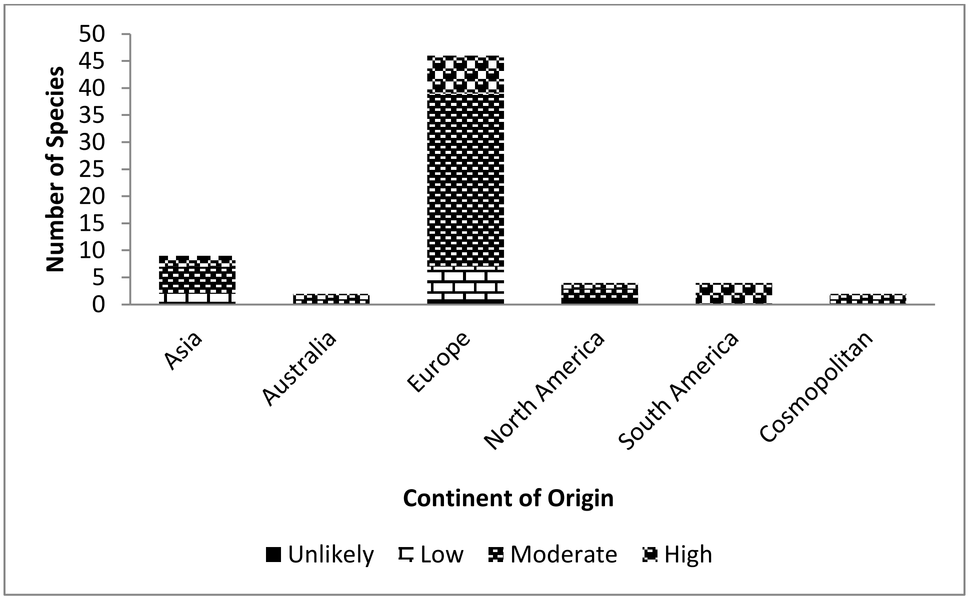

Figure 4: Likelihood of introduction of species by continent of origin.

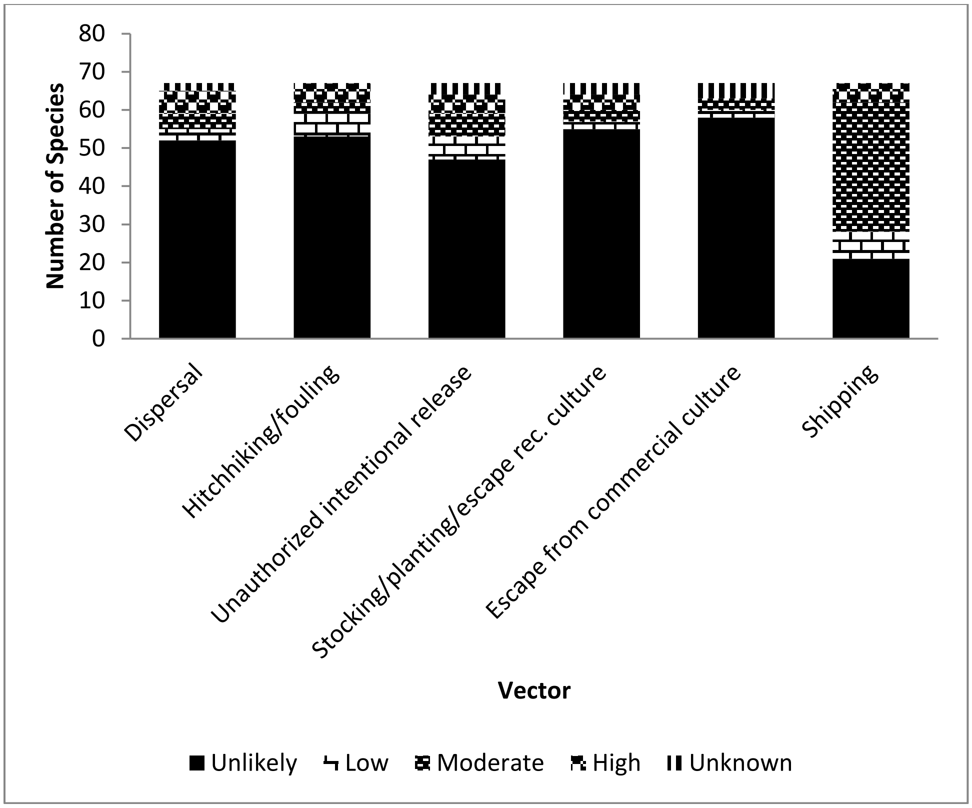

Figure 5: Likelihood of introduction of species by vector. The shipping vector was disproportionally responsible (50%) for the species with significant (high + moderate) potential for introduction to the Great Lakes basin.

Potential for Establishment

In the establishment assessment component, contributing variables were broadly grouped into a total of 18 questions within four categories: invasive biological/ecological attributes (environmental tolerance, overwintering, diet, competitive ability, fecundity, reproductive mode), environmental compatibility (climate, water quality, habitat, climate change, food availability, interspecific dependence/facilitation/inhibition), propagule pressure (inoculum size, frequency), and history of invasion and spread (extent, rate of spread, prevention). While important to successful establishment/spread, initially proposed questions concerning genetic diversity of potential source population, genetic and phenotypic variation, and likelihood of introduction during time of year appropriate for establishment, were deemed unlikely to be able to answer *a priori* for most species and removed from this assessment component. One question relating to propagule pressure was retained in the assessment; however, this question could not be answered for 39 of the 67 species (58%). Only an additional 48 questions (<5%) could not be answered with these being spread more evenly across the question types. In general, data was sufficient to complete the assessment. Confidence in the assessment was low for only four invertebrate species (*Ectinosoma abrau*, *Paraleptastacus spinicaudus triseta, Sinelobus stanfordi, and Leyogonimus polyoon*).

Overall species' establishment potential was determined by its total point score. Three questions included an adjustment factor that led to an overall reduction in a species' score. Such adjustments were warranted when a variable would counter or prevent the species' establishment. For example, if a critical prey species is not present in the Great Lakes, that reduces the likelihood of the species becoming established, even if all other factors would support its establishment. The categorical probability of introduction for each vector (High, Moderate, Low) was determined by the quantitative score.

Table 4: Probability of establishment for fishes in the Great Lakes basin. NE= Natural Enemy present in Great Lakes. C = Control measures in place in the Great Lakes.

Species	Invasive Biological or Ecological Attributes	Environmental Compatibility	Propagule Pressure	History of Invasion	Adjustment	**Overall**	# Unknowns & Confidence
Alburnus alburnus	39	50	Unknown	13		**102** **High**	1 High
Atherina boyeri	32	51	Unknown	11		**94** **Moderate**	2 Moderate
Babko gymnotrachelus	40	53	Unknown	14		**107** **High**	3 Moderate
Benthophilus stellatus	28	42	Unknown	10	-20% NE	**64** **Moderate**	1 High
Carassius carassius	31	49	0	9	-10%NE	**80** **Moderate**	0 High
Channa argus	48	35	Unknown	13		**96** **Moderate**	2 Moderate
Clupeonella cultriventris	30	44	Unknown	11	-10% NE	**77** **Moderate**	1 High
Cottus gobio	27	36	Unknown	5	-20% NE	**54** **Moderate**	2 Moderate
Ctenopharyngodon idella	32	45	4	18	-40% C	**59** **Moderate**	0 High
Cyprinella whipplei	19	45	Unknown	4	-10% NE	**61** **Moderate**	2 Moderate
Hypopthalmichthys molitrix	35	47	2	18	-40% C	**61** **Moderate**	0 High

Hypophthalmichthys nobilis	34	47	1	18	-40% C	**60** **Moderate**	0 High
Ictalurus furcatus	33	43	0	10		**86** **Moderate**	0 High
Knipowitschia caucasica	25	54	Unknown	7		**86** **Moderate**	2 Moderate
Leuciscus idus	32	41	Unknown	12		**85** **Moderate**	2 Moderate
Leuciscus leuciscus	29	44	Unknown	6		**79** **Moderate**	1 High
Neogobius fluviatilis	35	53	Unknown	13		**101** **High**	1 High
Oncorhynchus keta	33	48	2	3		**86** **Moderate**	0 High
Osmerus eperlanus	39	37	0	2	-20% NE	**62** **Moderate**	0 High
Perca fluviatilis	29	49	Unknown	17		**95** **Moderate**	1 High
Perccottus glenii	40	50	Unknown	18	-5% NE	**103** **High**	1 High
Phoxinus phoxinus	38	49	Unknown	9	-5% NE	**91** **Moderate**	1 High
Pseudorasbora parva	39	45	Unknown	18	-10% NE	**92** **Moderate**	1 High
Rutilus rutilus	37	55	Unknown	5	-10% NE	**87** **Moderate**	2 Moderate
Sander lucioperca	45	58	Unknown	13		**116** **High**	1 High

Silurus glanis	38	42	0	13		**93** **Moderate**	0 High
Syngnathus abaster	35	42	0	14	-10% NE	**82** **Moderate**	0 High

Table 5: Probability of establishment for invertebrates in the Great Lakes basin. NE= Natural Enemy present in Great Lakes. C = Control measures in place in the Great Lakes.

Species	Invasive Biological or Ecological Attributes	Environmental Compatibility	Propagule Pressure	History of Invasion	Adjustment	**Overall**	# Unknowns & Confidence
Limnoperna fortunei	40	56	0	13		**109** **High**	0 High
Monodacna colorata	27	46	Unknown	13		**86** **Moderate**	3 Moderate
Fredericella sultana	36	48	0	0		**84** **Moderate**	3 Moderate
Apocorophium lacustre	30	59	2	12		**103** **High**	1 High
Chelicorophium curvispinum	42	45	Unknown	16		**103** **High**	2 Moderate
Dikerogammarus haemobaphes	41	58	Unknown	16		**115** **High**	2 Moderate
Dikerogammarus villosus	48	57	Unknown	16		**121** **High**	1 High
Echinogammarus warpachowskyi	35	48	Unknown	10		**93** **Moderate**	1 High
Obesogammarus crassus	43	52	Unknown	13		**108** **High**	3 Moderate
Obesogammarus obesus	40	57	2	15	-10%NE	**103** **High**	1 High

Pontogammarus robustoides	49	51	Unknown	17		**117** **High**	2 Moderate
Cornigerius maeoticus maeoticus	36	49	1	14	-30%NE	**70** **Moderate**	0 High
Daphnia cristata	29	41	1	8	-10%NE	**71** **Moderate**	0 High
Podonevadne trigona ovum	34	50	Unknown	14	-10%NE	**88** **Moderate**	2 Moderate
Calanipeda aquaedulis	37	47	2	11	-10%NE	**87** **Moderate**	1 High
Cyclops kolensis	26	43	2	5	-10%NE	**68** **Moderate**	0 High
Ectinosoma abrau	17	25	Unknown	0		**42** **Low**	8 Low
Heterocope appendiculata	20	41	Unknown	9		**70** **Moderate**	4 Moderate
Heterocope caspia	25	50	Unknown	12		**87** **Moderate**	3 Moderate
Paraleptastacus spinicaudus triseta	17	25	Unknown	0		**42** **Low**	8 Low
Limnomysis benedeni	46	52	Unknown	18		**116** **High**	2 Moderate
Paramysis (Mesomysis) intermedia	29	47	Unknown	5		**81** **Moderate**	1 High
Paramysis (Metamysis) ullskyi	33	48	Unknown	8		**89** **Moderate**	2 Moderate
Paramysis (Serrapalpisis) lacustris	28	49	Unknown	18		**95** **Moderate**	4 Moderate

Cherax destructor	33	47	0	14	-10%NE -40%C	**51** **Moderate**	0 High
Rhithropanopeus harrisii	35	55	0	15		**105** **High**	1 High
Sinelobus stanfordi	20	26	0	4	-10%NE	**45** **Low**	6 Low
Leyogonimus polyoon	11	53	Unknown	11		**75** **Moderate**	6 Low
Hypania invalida	41	49	Unknown	12		**102** **High**	1 High
Brachionus leydigii	21	43	3	0		**67** **Moderate**	5 Moderate
Filinia cornuta	17	41	Unknown	7		**65** **Moderate**	5 Moderate
Filinia passa	18	40	3	8	-10%NE	**62** **Moderate**	3 Moderate

Table 6: Probability of establishment for plants in the Great Lakes basin. NE= Natural Enemy present in Great Lakes. C = Control measures in place in the Great Lakes.

Species	Invasive Biological or Ecological Attributes	Environmental Compatibility	Propagule Pressure	History of Invasion	Adjustment	**Overall**	# Unknowns & Confidence
Crassula helmsii	40	41	Unknown	10		**91** **Moderate**	1 High
Egeria densa	34	48	7	18	-10%NE -30%C	**67** **Moderate**	0 High
Eichhornia crassipes	34	44	6	18	-30%C	**71** **Moderate**	0 High
Hydrilla verticillata	35	51	3	18	-30%C	**75** **Moderate**	0 High

Hygrophila polysperma	36	39	2	12	-5%NE	**85** **Moderate**	0 High
Myriophyllum aquaticum	25	39	Unknown	14		**78** **Moderate**	2 Moderate
Pistia stratiotes	27	33	7	16	-30%C	**58** **Moderate**	0 High
Stratiotes aloides	34	43	0	7		**84** **Moderate**	0 High

Perhaps unsurprisingly given preselection of the list to be assessed, no species assessed with moderate to high confidence were found to have a low probability of establishment in the Great Lakes. Five fishes scored over 100 overall (of 144 possible) and were found to have a high probability of establishment of the Great Lakes (*Alburnus alburnus, Babko gymnotrachelus, Neogobius fluviatilis, Perccottus glenii*, and *Sander lucioperca*). Eleven invertebrates were also found to have a high probability of establishment (*Limnoperna fortunei, Apocorophium lacustre, Chelicorophium curvispinum, Dikerogammarus haemobaphes, Dikerogammarus villosus, Obesogammarus crassus, Obesogammarus obesus, Pontogammarus robustoides, Limnomysis benedeni, Rhithropanopeus harrisii* and *Hypania invalida).* The remaining 47 species were assessed as a moderate risk of establishment if introduced.

Potential for Impact

The impact assessment component was divided into sets of six questions within three potential impact categories: environmental impact, socioeconomic impact, and beneficial effect. The numerical values corresponding to each score worked in conjunction with the scoring system to ensure that species with highly significant impacts for any criterion ranked as a high potential impact species (>5) overall in that category. In contrast, moderately significant potential impacts in all six criteria were required to assess a species as having a high potential impact. A species could have only been ranked as a low potential impact species for a given category if it lacked potential impacts of high significance and demonstrated a limited number of moderately significant and unknown impacts for the six criteria. Overall, the full assessment could be completed only for 37 species (55%) due to lack of information. Information was insufficient to assess the potential environmental impact of 10 fish and 16 invertebrates; the socioeconomic impact of three fish and two invertebrates, and the benefits of one fish.

Table 7: Potential impact of fishes in the Great Lakes basin.

	Environmental	Socio-economic	Benefit	Total Unknowns
Alburnus alburnus	14 High	0 Low	7 High	1
Atherina boyeri	2 Moderate	0 Low	6 High	4

Babko gymnotrachelus	0 Unknown	1 Low	0 Unknown	8
Benthophilus stellatus	0 Unknown	0 Low	0 Low	5
Carassius carassius	0 Unknown	0 Low	2 Moderate	5
Channa argus	1 Unknown	2 Moderate	2 Moderate	3
Clupeonella cultriventris	0 Unknown	0 Low	1 Low	6
Cottus gobio	0 Unknown	0 Low	0 Low	6
Ctenopharyngodon idella	20 High	1 Low	8 High	1
Cyprinella whipplei	0 Unknown	0 Low	0 Low	6
Hypophthalmichthys molitrix	15 High	7 High	4 Moderate	2
Hypophthalmichthys nobilis	8 High	12 High	2 Moderate	3
Ictalurus furcatus	2 Moderate	1 Low	14 High	2
Knipowitschia caucasica	0 Unknown	0 Low	0 Low	4
Leuciscus idus	0 Unknown	0 Low	8 High	2
Leuciscus leuciscus	7 High	6 High	2 Moderate	3

Neogobius fluviatilis	3 Moderate	0 Low	2 Moderate	0
Oncorhynchus keta	3 Moderate	0 Low	12 High	1
Osmerus eperlanus	7 High	0 Unknown	3 Moderate	3
Perca fluviatilis	18 High	2 Moderate	12 High	2
Perccottus glenii	8 High	1 Low	2 Moderate	4
Phoxinus phoxinus	2 Moderate	1 Low	1 Low	2
Pseudorasbora parva	19 High	1 Unknown	0 Low	1
Rutilus rutilus	11 High	2 Moderate	2 Moderate	1
Sander lucioperca	8 High	0 Unknown	12 High	3
Silurus glanis	6 High	0 Low	8 High	1
Syngnathus abaster	1 Unknown	0 Low	0 Low	5

Table 8: Potential impact of invertebrates in the Great Lakes basin.

	Environmental	**Socio-economic**	**Benefit**	**Total Unknowns**
Limnoperna fortunei	30 High	9 High	7 High	0
Monodacna colorata	0 Unknown	0 Low	1 Low	2

Fredericella sultana	8 High	12 High	0 Low	3
Apocorophium lacustre	1 Unknown	0 Low	0 Low	4
Chelicorophium curvispinum	3 Moderate	0 Unknown	2 Moderate	1
Dikerogammarus haemobaphes	1 Unknown	0 Low	1 Low	1
Dikerogammarus villosus	7 High	0 Low	1 Low	1
Echinogammarus warpachowskyi	2 Moderate	0 Low	2 Moderate	4
Obesogammarus crassus	6 High	0 Low	0 Low	1
Obesogammarus obesus	8 High	0 Low	0 Low	4
Pontogammarus robustoides	4 Moderate	0 Low	2 Moderate	1
Cornigerius maeoticus maeoticus	0 Unknown	0 Low	0 Low	2
Daphnia cristata	0 Unknown	0 Low	2 Moderate	2
Podonevadne trigona ovum	2 Moderate	0 Low	0 Low	4
Calanipeda aquaedulis	1 Unknown	0 Low	0 Low	3
Cyclops kolensis	1 Unknown	0 Low	0 Low	6

Ectinosoma abrau	0 Unknown	0 Low	0 Low	6
Heterocope appendiculata	0 Unknown	0 Low	1 Low	6
Heterocope caspia	0 Unknown	0 Low	1 Low	6
Paraleptastacus spinicaudus triseta	0 Unknown	0 Low	0 Low	6
Limnomysis benedeni	4 Moderate	0 Low	2 Moderate	0
Paramysis (Mesomysis) intermedia	0 Unknown	0 Low	0 Low	6
Paramysis (Metamysis) ullskyi	7 High	0 Low	1 Low	3
Paramysis (Serrapalpisis) lacustris	3 Moderate	0 Low	1 Low	1
Cherax destructor	2 Moderate	1 Low	2 Moderate	3
Rhithropanopeus harrisii	0 Unknown	1 Low	1 Low	4
Sinelobus stanfordi	0 Low	0 Low	0 Low	1
Leyogonimus polyoon	1 Unknown	0 Unknown	0 Low	3
Hypania invalida	0 Low	0 Low	1 Low	0
Brachionus leydigii	0 Low	0 Low	0 Low	0

Filinia cornuta	0 Unknown	0 Low	0 Low	3
Filinia passa	1 Unknown	0 Low	0 Low	5

Table 9: Potential impact of plants in the Great Lakes basin.

	Environmental	**Socio-economic**	**Benefit**	**Total Unknowns**
Crassula helmsii	6 High	2 Moderate	0 Low	1
Egeria densa	18 High	25 High	3 Moderate	1
Eichhornia crassipes	15 High	26 High	4 Moderate	1
Hydrilla verticillata	19 High	30 High	5 High	2
Hygrophila polysperma	3 Moderate	8 High	3 Moderate	2
Myriophyllum aquaticum	18 High	3 Moderate	4 Moderate	5
Pistia stratiotes	14 High	30 High	4 Moderate	0
Stratiotes aloides	3 Moderate	2 Moderate	1 Low	1

Eleven fish species (*Alburnus alburnus, Hypophthalmichthys molitrix, Hypophthalmichthys nobilis, Leuciscus leuciscus, Osmerus eperlanus, Perca fluviatilis, Perccottus glenii, Pseudorasbora parva, Rutilus rutilus, Sander lucioperca,* and *Silurus glanis)* were found to have high potential environmental and/or socioeconomic impact as were six species of invertebrates (*Limnoperna fortunei, Fredericella sultana, Dikerogammarus villosus, Obesogammarus crassus, Obesogammarus obesus,* and *Paramysis (Metamysis) ullskyi)* and seven species of plants (*Crassula helmsii, Egeria densa, Eichhornia crassipes, Hydrilla verticillata, Hygrophila polysperma, Myriophyllum aquaticum,* and *Pistia stratiotes).* Ten fish species were determined to have a high potential beneficial impact, but only four of these *(Atherina boyeri, Ictalurus furcatus, Leuciscus idus,* and *Oncorhynchus keta)* did not also have high negative environmental or socioeconomic impacts.

An additional 11 species were found to have moderate environmental and/or socioeconomic impacts (*Channa argus, Neogobius fluviatilis, Phoxinus phoxinus, Chelicorophium curvispinum, Echinogammarus warpachowskyi, Pontogammarus robustoides, Podonevadne trigona ovum, Limnomysis benedeni, Paramysis (Serrapalpisis) lacustris, Cherax destructor,* and *Stratiotes aloides)* and one species *(Daphnia cristata)* had moderate benefits without offsetting high-moderate environmental or socioeconomic impacts.

3.2 Analyses

Overall risk posed by a species to the Great Lakes system was a function of the likelihood that it is introduced, the probability of it becoming established if introduced and the potential for it to have serious environmental or socioeconomic impacts in the event it does become established.

Table 10: Summary of overall risk for each species.

Species	**Introduction**	**Establishment**	**Environmental Impact**	**Socioeconomic Impact**	**Benefits**
Apocorophium lacustre	High	High	Unknown	Low	Low
Eichhornia crassipes	High	Moderate	High	High	Moderate
Pistia stratiotes	High	Moderate	High	High	Moderate
Hydrilla verticillata	High	Moderate	High	High	High
Hypophthalmichthys nobilis	High	Moderate	High	High	Moderate
Hypophthalmichthys molitrix	High	Moderate	High	High	Moderate
Egeria densa	High	Moderate	High	High	Moderate
Fredericella sultana	High	Moderate	High	High	Low
Myriophyllum aquaticum	High	Moderate	High	Moderate	Moderate
Rutilus rutilus	High	Moderate	High	Moderate	Moderate
Ctenopharyngodon idella	High	Moderate	High	Low	High
Stratiotes aloides	High	Moderate	Moderate	Moderate	Low
Ictalurus furcatus	High	Moderate	Moderate	Low	High
Leuciscus idus	High	Moderate	Unknown	Low	High

Daphnia cristata	High	Moderate	Unknown	Low	Moderate
Brachionus leydigii	High	Moderate	Low	Low	Low
Filinia cornuta	High	Moderate	Low	Low	Low
Filinia passa	High	Moderate	Low	Low	Low
Alburnus alburnus	Moderate	High	High	Low	High
Perccottus glenii	Moderate	High	High	Low	Moderate
Dikerogammarus villosus	Moderate	High	High	Low	Low
Obesogammarus crassus	Moderate	High	High	Low	Low
Chelicorophium curvispinum	Moderate	High	Moderate	Low	Moderate
Neogobius fluviatilis	Moderate	High	Moderate	Low	Moderate
Pontogammarus robustoides	Moderate	High	Moderate	Low	Moderate
Limnomysis benedeni	Moderate	High	Moderate	Low	Moderate
Dikerogammarus haemobaphes	Moderate	High	Unknown	Low	Low
Rhithropanopeus harrisii	Moderate	High	Unknown	Low	Low
Babko gymnotrachelus	Moderate	High	Unknown	Low	Unknown
Hypania invalida	Moderate	High	Low	Low	Low
Sander lucioperca	Low	High	High	Unknown	High
Obesogammarus obesus	Low	High	High	Low	Low
Leuciscus leuciscus	Moderate	Moderate	High	High	Moderate
Perca fluviatilis	Moderate	Moderate	High	Moderate	High
Osmerus eperlanus	Moderate	Moderate	High	Unknown	Moderate
Paramysis (Metamysis) ullskyi	Moderate	Moderate	High	Low	Low

Hygrophila polysperma	Moderate	Moderate	Moderate	High	Moderate
Atherina boyeri	Moderate	Moderate	Moderate	Low	High
Echinogammarus warpachowskyi	Moderate	Moderate	Moderate	Low	Moderate
Cherax destructor	Moderate	Moderate	Moderate	Low	Moderate
Paramysis (Serrapalpisis) lacustris	Moderate	Moderate	Moderate	Low	Low
Phoxinus phoxinus	Moderate	Moderate	Moderate	Low	Low
Channa argus	Moderate	Moderate	Unknown	Moderate	Moderate
Cottus gobio	Moderate	Moderate	Unknown	Low	Low
Cyprinella whipplei	Moderate	Moderate	Unknown	Low	Low
Knipowitschia caucasica	Moderate	Moderate	Unknown	Low	Low
Syngnathus abaster	Moderate	Moderate	Unknown	Low	Low
Monodacna colorata	Moderate	Moderate	Unknown	Low	Low
Cornigerius maeoticus	Moderate	Moderate	Unknown	Low	Low
Calanipeda aquaedulis	Moderate	Moderate	Unknown	Low	Low
Cyclops kolensis	Moderate	Moderate	Unknown	Low	Low
Heterocope appendiculata	Moderate	Moderate	Unknown	Low	Low
Heterocope caspia	Moderate	Moderate	Unknown	Low	Low
Paramysis (Mesomysis) intermedia	Moderate	Moderate	Unknown	Low	Low
Leyogonimus polyoon	Moderate	Moderate	Unknown	Unknown	Low
Paraleptastacus spinicaudus triseta	Moderate	Low	Unknown	Low	Low
Sinelobus stanfordi	Moderate	Low	Low	Low	Low
Limnoperna fortunei	Low	High	High	High	High
Crassula helmsii	Low	Moderate	High	Moderate	Low
Pseudasbora parva	Low	Moderate	High	Unknown	Low

Siluris glanis	Low	Moderate	High	Low	High
Podonevadne trigona ovum	Low	Moderate	Moderate	Low	Low
Oncorhynchus keta	Low	Moderate	Moderate	Low	High
Benthophilus stellatus	Low	Moderate	Unknown	Low	Low
Carassius carassius	Low	Moderate	Unknown	Low	Moderate
Clupeonella cultriventris	Low	Moderate	Unknown	Low	Low
Ectinosoma abrau	Low	Low	Unknown	Low	Low

Apocorophium lacustre has the distinction of being the only species in our assessment to score both highly likely to be introduced and highly likely to become established. Unfortunately, data were insufficient to assess its potential environmental impact. This species should be a priority for future assessment.

Fifteen species scored as highly likely to be introduced and moderately likely to become established while 12 species scored as moderately likely to be introduced and highly likely to become established if introduced. These species should be considered as having an overall assessment to this point of moderately likely to be both introduced and established. Of these 27 species, 14 were identified as likely to have high environmental and/or socioeconomic impacts in the event of establishment. These species included five plants (*Eichhornia crassipes, Pistia stratiotes, Hydrilla verticillata, Egeria densa,* and *Myriophyllum aquaticum),* six fishes *(Hypophthalmichthys nobilis, Hypophthalmichthys molitrix, Rutilus rutilus, Ctenopharyngodon idella, Alburnus alburnus,* and *Perccottus glenii),* and three invertebrates *(Fredericella sultana, Dikerogammarus villosus,* and *Obesogammarus crassus)* which should be considered to pose the greatest threat to the Great Lakes.

Five species (*Leuciscus leuciscus, Perca fluviatilis, Osmerus eperlanus* , *Paramysis ullskyi* and *Hygrophila polysperma)* were assessed as moderately likely to be introduced and moderately likely to become established as well as having high potential for environmental or socioeconomic impacts. These species can be considered to have only a slightly lower likelihood of posing a significant threat to the Great Lakes relative to the previous fourteen.

Two species (*Sander lucioperca* and *Obesogammarus obesus*) that were assessed as having a low probability of introduction had a high probability of establishment and subsequent high impact.

Within this dataset, likelihood of introduction and establishment did not correlate (see Figure 6); although introduction is a necessary prerequisite for establishment, it was not itself a good predictor of whether or not a species will be able to establish.

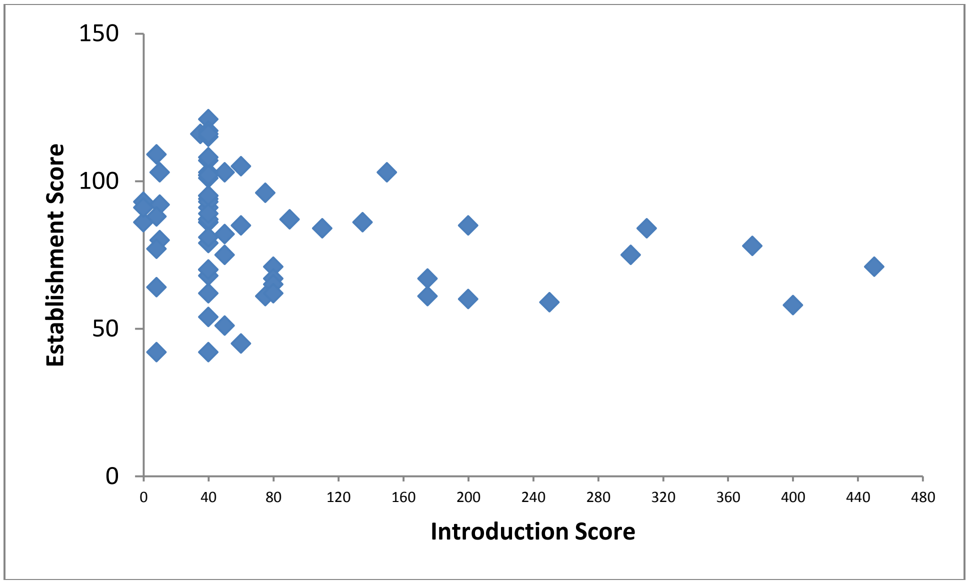

Figure 6: The likelihood of introduction does not correlate with the likelihood of a species becoming established after introduction.

Similarly, neither introduction nor establishment scores are good predictors of an organism's potential impact (see Figure 7).

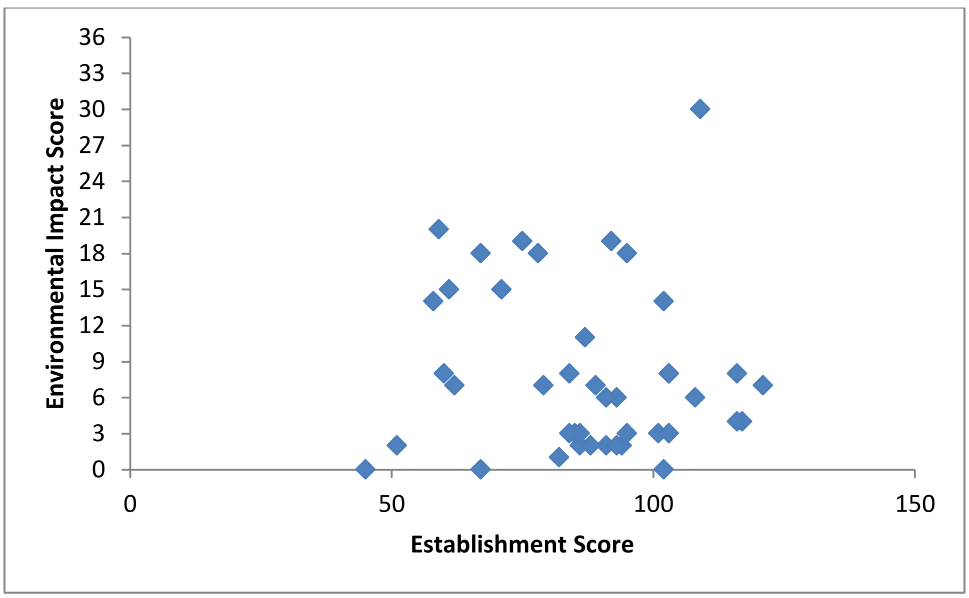

Figure 7: The likelihood of establishment is not correlated with an organisms potential environmental impact.

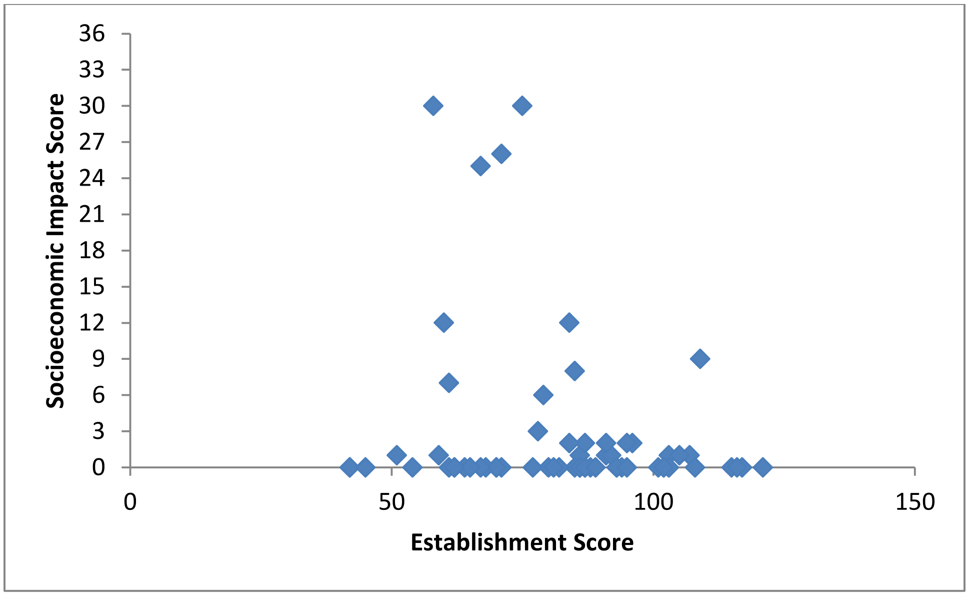

Figure 8: The likelihood of establishment is not correlated with an organisms potential socio-economic impact.

4. DISCUSSION

This assessment provides a unique opportunity to compare the overall risk posed by various species across all taxa. While somewhat skewed by the biases of the available scientific literature (e.g., ready availability of data on ballast-water mediated invaders of Eurasian origin in contrast to lack of information other vectors, source populations, and taxa) and the limitations of such (e.g., data was insufficient to assess potential environmental impacts for many species) as well as providing only a semi-quantitative assessment, nonetheless it provides insight into the patterns of invasion threats facing the Great Lakes region. This risk assessment approach has advantages in that it is relatively quick, most needed information is readily available, it allows cross-taxa comparisons, and it supports decision-making. Other strengths of the tool include assessment of the full suite of positive and negative impacts to account for multiple stakeholder values in light of potential consequences, as well as pan-invasion stages (introduction, establishment, consequence) to gauge risk more fully.

Like most risk assessments, this framework was faced with the challenge of addressing uncertainty, both in its development and its application to the Great Lakes watchlist. In applying the framework to the Great Lakes watchlist, most of the uncertainty was epistemic in nature and associated with the environmental impact component. Uncertainty resulted in low confidence in the outcome with regard to introduction for only 1 specie (1%) and with regard to establishment for only 4 species (6%). Assessment of potential benefits was limited for only 1 specie (1%) and assessment of potential socioeconomic impact limited for only 5 species (7%). In contrast, assessment of potential environmental impact was limited for 26 species (39%); however, this seems more a limitation of the availability of environmental knowledge than of risk assessment per se given that in a similar assessment of the impact of established invaders nearly half (49%) of species could not be assessed due to insufficient information (Sturtevant et al 2014).

Despite the overall shipping bias, species with a high potential for introduction—including those of a particular taxonomic group (e.g., fishes, plants)—were fairly evenly distributed among vectors. All assessed taxonomic groups had members with high-moderate potential for introduction. This suggests that managers need to go beyond single vector- or taxon-based assessments when developing their prevention and monitoring strategies.

This study identified a subset of 16 species which should be considered the highest overall risk (introduction + establishment + impact) to the Great Lakes region. These include five plants (*Eichhornia crassipes, Pistia stratiotes, Hydrilla verticillata, Egeria densa,* and *Myriophyllum aquaticum),* six fishes *(Hypophthalmichthys nobilis, Hypophthalmichthys molitrix, Rutilus rutilus, Ctenopharyngodon idella, Alburnus alburnus,* and *Perccottus glenii),* and four invertebrates *(Apocorophium lacustre, Fredericella sultana, Dikerogammarus villosus,* and *Obesogammarus crassus).* Fact sheets have been developed for each of these species (available through GLANSIS http://www.glerl.noaa.gov/res/Programs/glansis/glansis.html) which provide information on identification, life history, ecology, invasion history, risk assessment, potential impacts, and management options as well as a summary of the individual risk assessment. It is our intent that this information resource should assist managers in targeting prevention programs, early detection and rapid response.

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APPENDIX A. RISK ASSESSMENTS

A.1 Fishes

Scientific Name: *Alburnus alburnus*
Linnaeus, 1758

Common Name: Bleak, Alver

Synonyms:

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: Unlikely

Hitchhiking/fouling: Unlikely

Unauthorized intentional release: Unlikely

Stocking/planting/escape from recreational culture: Unlikely

Escape from commercial culture: Unlikely

Transoceanic shipping: Moderate

***Alburnus alburnus* has a moderate probability of introduction to the Great Lakes (Confidence level: High).**

Potential pathway(s) of introduction: Transoceanic Shipping (ballast water)

From its native range, *Alburnus alburnus* was locally introduced to the Iberian Peninsula, Spain, Portugal, and Italy (Kottelat 1997). This fish species was intentionally introduced to the Northern Iberian watershed by anglers in an attempt to increase the stock of forage for nonnative fish predators and was used as a popular live baitfish (Vinyoles et al. 2007). *Alburnus alburnus* is found in the Seine, Loire, and Rhine Rivers, which naturally discharge into the Atlantic Ocean (Leuven et al. 2009). It occurs in ports that have direct trade connections with the Great Lakes.

Through ballast exchange practices, *A. alburnus* may experience high mortality due to its inability to survive waters with high salinity, limiting its introduction to the Great Lakes (Wheeler 1978a). However, it has been shown that 35% of "No Ballast on Board" (NOBOB) vessels, which are exempt from mandatory ballast exchange, possess at least 1 tank with ≤ 5‰ salinity, thus enhancing the potential for *A. alburnus* to survive transport overseas to be introduced into the Great Lakes (Niimi and Reid 2003).

Currently, the geographical distribution of *Alburnus alburnus* does not cover water bodies connected to the Great Lakes basin. *Alburnus alburnus* is not a popular aquarium fish and is not available for purchase online. *Alburnus alburnus* is not available as live baitfish for online purchase in North America. There are import restrictions regarding the transport of *Alburnus alburnus* to the United Kingdom (Clarke 2006). It is predicted that the geographical range of this species will expand due to climate change (Lehtonen 1996).

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100
No, this species does not occur near waters connected to the Great Lakes basin and/or is not mobile or able to be transported by wind or water.	0 √
Unknown	U

- Alburnus alburnus *resides in slow flowing streams and temperate lakes located in Europe and Asia. Its native range extends north of the Pyrenees, Caucasus, and Alps, and eastward toward the Ural and Emba rivers. It was later locally introduced to the Iberian Peninsula and is found in Spain, Portugal, and Italy (Kottelat 1997).*

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0 √
Unknown	U

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a) Is this species sold at aquarium/pet/garden stores ("brick & mortar" or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100
No, this species this species is rarely/never sold.	0 √
Unknown	U

- Alburnus alburnus *is not a popular aquarium fish or available for purchase online. Import restrictions have been placed on the transfer of* Alburnus alburnus *to the United Kingdom (Clarke 2006).*
- Alburnus alburnus *was locally introduced in the Northern Iberian watershed as a result of anglers purposefully releasing it as a forage fish (Vinyoles et al. 2007). It is also a popular live baitfish when targeting predatory fish such as pike and perch (Vinyoles et al. 2007).*
- Alburnus alburnus *is not available for purchase as a live baitfish in North America through online vendors.*
- *There is no evidence to suggest that* Alburnus alburnus *is easily obtained even within its native range; therefore, obtaining it in the Great Lakes region would also be very difficult and highly unlikely.*

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0 √
Unknown	U

- Alburnus alburnus *is not stocked near the Great Lakes.*

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is likely to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces), this activity may occur within 20 km of the basin because of the species' popularity/value.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100
No, this species is not commercially cultured in or transported through the Great Lakes region.	0 √
Unknown	U

- Alburnus alburnus *scales are used in the artificial pearl trade and this fish is harvested commercially in the Seine, Loire, and the Rhine rivers (Denton and Nicol 1965). However, such commercial activity is limited to Europe.*

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80 √
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40
No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0
Unknown	U

- Alburnus alburnus *is a brackish water fish that lives in a salinity of 8-10 ‰ (Linden et al. 1979). Due to its stenohaline nature, survival of ballast water regulations is unlikely (Wheeler 1978a).*
- *Myers (1949) categorizes Cyprinidae as strictly intolerant of salt water. There is no indication that* A. alburnus *exhibits avoidance behaviors that would allow it to survive transport.*
- *Niimi and Reid (2003) measured the salinity of 'No Ballast on Board' or NOBOB vessels which are exempt from mandatory ballast exchange. Out of the 26 vessels measured, 35% had at least one tank with ≤ 5 ‰ salinity. It is possible that the bleak would be able to survive transport under these conditions.*

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5 √
Yes, but this species has neither been observed in ballast/fouling ships entering the Great Lakes nor in ports in direct trade with the Great Lakes.	Score x 0.1
No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0
Unknown	U

- Alburnus alburnus *is found in the Seine, Loire, and Rhine rivers, which naturally discharge into the Atlantic Ocean (Leuven et al. 2009). The Rhine first discharges into the North Sea, which connects to the Atlantic Ocean.*
- Alburnus alburnus *occurs in the Iberian Peninsula and is found in Spain, Portugal, and Italy (Kottelat 1997, Vinyoles et al. 2007). There are many ports in the Iberian Peninsula that have direct connections with the Great Lakes.*

Vector Potential Scorecard				
Vector	**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind	**0**	x	**0**	Unlikely
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.	**0**	x	**0**	Unlikely
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)	**0**	x	**0**	Unlikely
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)	**0**	x	**0**	Unlikely
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)	**0**	x	**0**	Unlikely
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling	**80**	x 0.5	**40**	Moderate
Total Unknowns (U)	**0**	**Confidence Level**	High	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

ESTABLISHMENT POTENTIAL RESULTS

Status: **Not established in North America, including the Great Lakes**

***Alburnus alburnus* has a high probability of establishment if introduced to the Great Lakes**

(Confidence level: High).

Following its introduction into the Ebro basin in Spain, this species rapidly established throughout the entire Iberian Peninsula, where it is currently present in all of the major Iberian water basins and a large number of Iberian rivers, suggesting that it has the ability to adapt to a warmer climate regime (Vinyoles et al. 2007). After its establishment in Britain, *Alburnus alburnus* consequently spread and established in Cyprus. It is believed that the high fecundity rate of this species is responsible for its establishment. It is a multiple spawner, so it spawns more frequently than *Rutilus rutilus* (Rinchard and Kestemont 1996). Where it has been introduced, *Alburnus alburnus* produces stunted populations that produce a large number of individuals that mature early at a small size (Welcomme 1988).

If *Alburnus alburnus* were introduced to the Great Lakes, it has the potential to spread rapidly (Kolar and Lodge 2002). The climate of the Great Lakes is similar to the native range of *Alburnus alburnus* and this species is likely capable of enduring overwintering conditions in the Great Lakes basin (Grigorovich et al. 2003, Reid and Orlova 2002, USEPA 2008). It is likely that the Great Lakes contain an abundant food source for this species. This species has a high reproductive rate (Vinyoles et al. 2007). It has not been reported that any natural enemy of *Alburnus alburnus* such as the tapeworm *Ligula intestinalis*, occurs in the Great Lakes region. In the Thames River, *Ligula intestinalis* preferentially parasitizes *Alburnus alburnus*, which impairs its swimming ability and increases the risk of predation (Harris and Wheeler 1974).

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
	7

- Alburnus alburnus *typically lives in a temperature range of 10-20*°C *(Baensch and Riehl 1991).*
- *A study regarding lethal temperature for various fish species indicates that the* A. alburnus' *lethal temperature range is 37.7-40.6°C at acclimation temperatures from 25.0-27.8°C in a lake environment where temperature was gradually raised per hour (Horoszewicz 1973).*
- Alburnus alburnus *is a brackish water fish that typically lives in salinities of 8-10 parts per thousand (Linden et al. 1979). There is no information to indicate that* A. alburnus *would be able to survive higher salinities.*
- *A study indicates that* A. alburnus *does not withstand oxygen-stressed environments particularly well (Willemsen 1980).*
- Alburnus alburnus *is tolerant to pollutants such as brominated flame retardents (Eljarrat et al. 2005).*
- *According to Souchon and Tissot (2012), 14°C is the minimum temperature tolerated for reproduction.*

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9
Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
	8

- *Due to the climatic similarities between the Great Lakes and Ponto-Caspian regions (Reid and Orlova 2002)* Alburnus alburnus *most likely endures similar overwintering conditions in its native range.*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
	7

- Alburnus alburnus *feeds on zooplankton and insects in the epilimnion.* Alburnus alburnus *is described to have a limited diet in comparison with the roach,* Rutilus rutilus, *a generalist (Keckeis and Schiemer 1990).*
- *Vinyoles et al. (2007) cited* A. alburnus' *prey as widespread and attributes this characteristic to its successful establishment outside its native range.*

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	0
Unknown	U
	6

- Alburnus alburnus *is currently threatening endemic species in the Iberian watershed due to its high reproductive rate and hybridization with other cyprinids (Vinyoles et al. 2007).*

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
	8

- *The bleak's high fecundity has allowed it to become established in Cyprus where it was accidentally introduced, as well as in the Iberian watershed (Vinyoles et al. 2007).*
- Alburnus alburnus *and* Blicca bjoerkna *are multiple spawners which spawn more frequently than the single spawner* Rutilus rutilus *(Rinchard and Kestemont 1996). Compared to* R. rutilus *and* B. bjoerkna*,* A. alburnus *has a relatively moderate gonadosomatic index.*
- *Where it is introduced,* A. alburnus *produces stunted populations that produce a large number of individuals that mature early at a small size (Welcomme 1988).*

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self-fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
	3

- *Where it is introduced,* Alburnus alburnus *produces stunted populations that produce a large number of individuals that mature early at a small size (Welcomme 1988).*

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- *The surface water temperature range of the water in the Ponto-Caspian region is similar to many of the lakes in the Great Lakes region (Reid and Orlova 2002).*
- *The Great Lakes and Ponto-Caspian region are "climatically compatible," which is one of the attributing factors to the success of Ponto-Caspian species in the Great Lakes (Reid and Orlova 2002).*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- *The Ponto-Caspian (Caspian, Azov, and Black seas) have similar climate and surface water temperature ranges as the Great Lakes (Grigorovich et al. 2003, Reid and Orlova 2002, USEPA 2008).*
- *Great Lakes underwent similar anthropogenic eutrophication as the Ponto-Caspian region (Reid and Orlova 2002).*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0
Unknown	U
	8

- *The bleak tends to live in shoals near the surface of slow-moving streams and lakes (Kottelat 2012, Linden et al. 1979). Bleak larvae inhabit the littoral zone of rivers/lakes and juveniles occur in a pelagic habitat (Kottelat 2012).*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0
Unknown	U
	9

- *Lehtonen (1996) predicted that European fish assemblages will shift toward cyprinid dominance and that* A. alburnus's *range will expand as a result of global climate change.*
- *The Bleak's establishment in the Iberian watershed (Vinyoles et al. 2007) points toward its ability to adapt to a warmer climate regime.*

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
	8

- *The widespread nature of the Bleak's prey has allowed it to successfully expand throughout its native and introduced ranges (Vinyoles et al. 2007). It is likely that the Bleak would have an abundant food source in the Great Lakes.*

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being	9

assessed; OR, No, there is no critical species required by the species being assessed	
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Great Lakes and is not likely to be introduced	-80% total points (at end)
Unknown	U
	9

- *There is no evidence to indicate that the Bleak requires another species to survive during critical stages in its life cycle.*

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes)	6
Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0
Unknown	U
	0

- *There is no evidence to indicate that* A. alburnus *would benefit from the spread of another species already in the Great Lakes.*

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the	-80% total points (at end)

Great Lakes)	
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0
Unknown	U
	0

- *There have been reports of the tapeworm* Ligula intestinalis *preferentially parasitizing* Alburnus alburnus *in the River Thames (Harris and Wheeler 1974). Infestation may cause impairment of swimming ability (Harris and Wheeler 1974), which can increase the risk of predation. Generally, however, infestation does not lead to death of the host.* Ligula intestinalis *has not been reported to occur in the Great Lakes region.*
- *There is no indication of a natural enemy/predator that would prevent the establishment of the Bleak.*

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9
Frequent, moderate inocula	6
Frequent, small inocula OR infrequent, large inocula	3
Infrequent, small or moderate inocula	0
Unknown	U
	U

- *When a ship enters the Great Lakes it discharges approximately 3 million liters of ballast water (Ricciardi and MacIsaac 2000).*
- *Shipping traffic from Western Europe through the St. Lawrence Seaway is a major contributor of ballast water discharge that enters the Great Lakes (USEPA 2008).*

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close	3

proximity to each other)	
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
	4

- *The Bleak was introduced northern Iberian watershed and is now present in all major Iberian water basins and a large number of Iberian rivers (Vinyoles et al. 2007).*
- *Vinyoles et al. (2007) also noted that* Alburnus alburnus *has been introduced to Cyprus from Britain where it has established a breeding population.*

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
	9

- *Following its introduction into the Ebro basin,* Alburnus alburnus *quickly spread throughout the entire Iberian Peninsula, where it is currently present in all major Iberian basins (Vinyoles et al. 2007).*
- *Kolar and Lodge (2002) predicted that the Bleak would spread quickly if introduced to the Great Lakes.*

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing the establishment and spread of this species)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent the establishment and/or spread of this species	0
Unknown	U
	0

- *There are no existing control measures in the Great Lakes to prevent the spread of the Bleak.*

Establishment Potential Scorecard				
Points	**Probability for Establishment**	A. Total Points (pre-adjustment)		102
>100	High	**Adjustments**		
		B. Critical species	A*(1- 0%)	102
51-99	Moderate	C. Natural enemy	B*(1- 0%)	102
		Control measures	C*(1- 0%)	102
0-50	Low	**Potential for Establishment**		High
# of questions answered as "unable to determine"	**Confidence Level**			
0-1	High	Total # of questions unknown		1
2-5	Moderate			
6-9	Low	Confidence Level		High
>9	Very low			

Section C: Potential for Impact

IMPACT POTENTIAL RESULTS

Environmental: High

Socio-Economic: Low

Beneficial: High

***Alburnus alburnus* has the potential for high environmental impact if introduced to the Great Lakes.**

Alburnus alburnus is a superior competitor because of its high reproductive rate, its non-specific diet, and its ability to tolerate a broad range of temperatures. *Alburnus alburnus* exhibits large and sudden bursts in population size so it has outcompeted native species where established (Pérez-Bote et al. 2004, Vinyoles et al. 2007, Welcomme 1988). In a study done by Maceda-Veiga et al. (2010) *Alburnus alburnus* was the second most frequently occurring fish sampled in the catchments of Catalonia, Spain. The authors also noted that native fish populations declined by an average 60% in the Catalonian catchments, and amphidromous species *A. arcasii* had experienced local extinctions. It is able to hybridize with other cyprinids (Maceda-Veiga et al. 2010, Blachuta and Witkowski 1984, Crivelli and Dupont 1987). In the Iberian watershed, *Alburnus alburnus* threatens endemic species through hybridizing with other cyprinids and its generally high reproductive rate (Vinyoles et al. 2007). Besides impacting native fish fauna, *Alburnus alburnus* feeds on cladoceran and other small invertebrates that play an important role in freshwater ecosystems and directly affect the water quality (Maceda-Veiga et al. 2010). This species exhibits a high level of plasticity in population traits and is able to adapt to a wide variety of environmental conditions. The mortality rate of *Alburnus alburnus* is higher in rivers than in lakes, but reproduction rates are higher in rivers (Almeida et al. 2014).

There is little or no evidence to support that *Alburnus alburnus* has the potential for significant socio-economic impact if introduced to the Great Lakes.

Alburnus alburnus may affect water quality by feeding on organisms that play a direct role in water quality (Maceda-Veiga et al. 2010).

***Alburnus alburnus* has the potential for high beneficial effects if introduced to the Great Lakes.**

This species may be commercially valuable as forage fish and baitfish (Pérez-Bote et al. 2004), and the artificial pearl trade (Denton and Nicol 1965). In Europe, it has been introduced into various reservoirs to benefit the populations of exotic fish predators such as the Northern Pike (*Esox Lucius*), Largemouth Bass (*Micropterus salmoides*), Zander (*Sander lucioperca*), and Wells Catfish (*Silurus glanis*) (Maceda-Veiga et al. 2010).

Establishment of *Alburnus alburnus* may increase productivity of predator fish in the Great Lakes, especially for predatory fish that do not have specific diets.

POTENTIAL ENVIRONMENTAL IMPACT

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1
Not significantly	0 √
Unknown	U

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6 √
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1
Not significantly	0
Unknown	U

- Alburnus alburnus *possesses a suite of life history traits that makes it a superior competitor. Its speed and specialization in surface-oriented feeding gives it a competitive advantage over fishes that only occasionally feed on the surface. Furthermore, this species' high fecundity allows it to displace other species. Bleak experiences large and sudden population increases that easily overpower and outcompete species already present. Such situations have been observed in Iberian rivers (Pérez-Bote et al. 2004, Vinyoles et al. 2007,* *Welcomme 1988). Other factors that may contribute to the bleak's superior competitive abilities include its ability to exploit a widespread spectrum of prey and its wide temperature tolerance (Biró and Muskó 1995, Chappaz et al. 1987, Mehner et al. 2005).*

- *In a study done by Maceda-Veiga et al. (2010)* A. alburnus *was found to be the second highest non-native occurring fish in sampled catchments in Catalonia, Spain. Maceda-Veiga et al. noted that endemic fish populations have declined greatly (by a mean of 60%) in the Catalonian catchments even to the extent that the amphidromous species* A. arcasii *has suffered local extinctions. The article hypothesized that in addition to habitat alteration, introduced species such as* C. carpio *and* A. alburnus *have an impact on native fish fauna.*

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in the food web)	6
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	1
Not significantly	0
Unknown	U √

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6 √
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0
Unknown	U

- *Bleak hybridizes easily with other cyprinids (Blachuta and Witkowski 1984, Crivelli and Dupont 1987).* Squalius alburnoides *resulted as a hybridization of* Squalius*, Bleak, and* Anaecypris.

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1 √
Not significantly	0
Unknown	U

- *Besides its impact on native fish fauna, Bleak feeds on cladoceran and other small invertebrates that play an important role in these ecosystems and directly affect the water quality (Maceda-Veiga et al. 2010).*

- *Horppila and Kairesalo (1992) examined the effects of* A. alburnus *on water quality by placing the fish in enclosures in the field. Algal production and chlorophyll-α levels were over two times more than enclosures without* A. alburnus.

E6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1 √
Not significantly	0
Unknown	U

- *Field studies suggest that a Bleak population can increase algal productivity and biomass (Horppila and Kairesalo 1992).*

Environmental Impact Total	**14**
Total Unknowns (U)	**1**

Scoring		
Score	# U	Impact
>5	Any	**High**
2-5	Any	Moderate
0	0-1	Low
1	0	
0	≥2	Unknown
1	≥1	

POTENTIAL SOCIO-ECONOMIC IMPACT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1
Not significantly	0 √
Unknown	U

S2) Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1
Not significantly	0 √
Unknown	U

S3) Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0 √
Unknown	U

S4) Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's	6

value for future generations	
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

Socio-Economic Impact Total	**0**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**Low**
1	0	
0	≥2	Unknown
1	≥1	

POTENTIAL BENEFICIAL EFFECT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular effect. An "Unknown" response is appropriate if the potential for a particular effect might be inferred but has not been explicitly reported or if there is an unresolved debate about a particular effect.

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1
Not significantly	0 √
Unknown	U

B2) Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?

Yes, it is economically important to at least one of these industries	6 √
Yes, but its economic contribution is small	1
Not significantly	0
Unknown	U

- Alburnus alburnus *is exploited commercially in parts of Europe, as a baitfish or forage fish (Elvira 1995, Pérez-Bote et al. 2004) and in the pearl trade (Denton and Nicol 1965). Additionally, Bleak have being* *introduced into various reservoirs in order to improve the populations of exotic fish predators such as the Northern Pike (*Esox lucius*), the Largemouth Bass (*Micropterus salmoides*), the Zander (*Sander lucioperca*), and the Wells Catfish (*Silurus glanis*) (Maceda-Veiga et al. 2010).*

B3) Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local communities and/or tourism	6
It is sometimes employed recreationally, but adds little value to local communities or tourism	1
Not significantly	0 √
Unknown	U

B4) Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR It is potentially important to medicine or research and is currently being or scheduled to be studied	1
Not significantly	0 √
Unknown	U

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1
Not significantly	0 √
Unknown	U

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1 √
Not significantly	0
Unknown	U

- *Bleak have being frequently used to enhance the populations of exotic fish predators such as the Northern Pike (*Esox lucius*), the Largemouth Bass (*Micropterus salmoides*), the zander (*Sander lucioperca*) and the Wells Catfish (*Silurus glanis*) (Maceda-Vega et al. 2010).*

Beneficial Effect Total	**7**
Total Unknowns (U)	**0**

Scoring		
Score	# U	**Impact**
>5	Any	**High**
2-5	Any	Moderate
0	0-1	Low
1	0	
0	≥2	Unknown
1	≥1	

Scientific Name: *Atherina boyeri*
Risso, 1810

Common Name: Big-scale Sand Smelt, Boyer's Sand Smelt, Black Sea Silverside

Synonyms:

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: Unlikely

Hitchhiking/fouling: Unlikely

Unauthorized intentional release: Unlikely

Stocking/planting/escape from recreational culture: Unlikely

Escape from commercial culture: Unlikely

Transoceanic shipping: Moderate

***Atherina boyeri* has a moderate probability of introduction to the Great Lakes (Confidence level: High).**

Potential pathway(s) of introduction: Transoceanic shipping (ballast water)

Atherina boyeri does not currently occur near waters connected to the Great Lakes. There is no indication that this species is sold or stocked in North America. However, it occurs in ports that have direct connections with the Great Lakes (NBIC).

Atherina boyeri has commercial value as a prey of highly-priced carnivorous fish such as sea bass, *Dicentrarchus labrax*. This species is introduced into freshwater lakes and reservoirs in Europe to enhance stock (Economidis et al. 2000). In Turkey, it has been introduced to several lakes by local fishermen (Innal and Erk'akan 2006). It can survive in hypersaline conditions up to 110% salinity and temperatures between 6-25°C (Henderson and Bamber 1987). It is likely that *Atherina boyeri* has the potential to survive ballast tank environments.

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100
No, this species does not occur near waters connected to the Great Lakes basin and/or is	0 √

not mobile or able to be transported by wind or water.	
Unknown	U

- Atherina boyeri *is a Ponto-Caspian fish that is also found in Portugal and Spain toward Nouadhibou in Mauritania and Madeira (Quignard and Pras 1986). Also found in the Mediterranean (Whitehead et al. 1986). There are isolated populations on the coasts of England and the Netherlands.*
- Atherina boyeri *does not occur in North America (Kolar and Lodge 2002).*

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0 √
Unknown	U

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a) Is this species sold at aquarium/pet/garden stores ("brick & mortar" or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100
No, this species this species is rarely/never sold.	0 √
Unknown	U

- Atherina boyeri *is a relatively important commercial fish in Greece (Leonardos and Sinis 2000).*
- *While commonly fried in some European and Middle Eastern cuisines (İzci et al. 2011), it does not appear to be sold in live trade.*

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1
Unknown	U

- *No data were found about this species in the United States.*

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0 √
Unknown	U

- *No data were found about this species in the United States.*

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is likely to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces), this activity may occur within 20 km of the basin because of the species' popularity/value.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100
No, this species is not commercially cultured in or transported through the Great Lakes region.	0 √
Unknown	U

- *While this species has been used for fishery purposes in some countries, no information was found regarding its fishery in the United States.*

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80 √
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40
No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0
Unknown	U

- *This species is a Ponto-Caspian atherinid fish identified as having high probability of invasion if introduced to the Great Lakes (Kolar and Lodge 2002). Its potential pathway of introduction is ballast water.*
- Atherina boyeri *is a very euryhaline species and can survive in temperatures 6-25˚C.*
- Atherina boyeri *can tolerate fresh to hypersaline waters (Henderson and Bamber 1987, Leonardos and Sinis 2000).*

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5 √
Yes, but this species has neither been observed in ballast/fouling ships entering the Great Lakes nor in ports in direct trade with the Great Lakes.	Score x 0.1
No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0
Unknown	U

- A. boyeri *occurs on the coasts of England, such as the Cornish coast (located along southern England) (Clowes 1884). There are several ports along the southern coast of England that are in direct trade with the Great Lakes.*

Vector Potential Scorecard				
Vector	**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind	**0**	x	**0**	Unlikely
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.	**0**	x	**0**	Unlikely
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)	**0**	x	**0**	Unlikely
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)	**0**	x	**0**	Unlikely
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)	**0**	x	**0**	Unlikely
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling	**80**	x 0.5	**40**	Moderate
Total Unknowns (U)	**0**	**Confidence Level**	High	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High

40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

ESTABLISHMENT POTENTIAL RESULTS

Status: **Not established in North America, including the Great Lakes**

***Atherina boyeri* has a moderate probability of establishment if introduced to the Great Lakes (Confidence level: Moderate).**

The native and introduced ranges of *Atherina boyeri* have similar climatic and abiotic conditions to that of the Great Lakes (Grigorovich et al. 2003, Reid and Orlova 2002, USEPA 2008). If introduced, *Atherina boyeri* is likely to find a suitable habitat in the Great Lakes. Although it is commonly found in estuaries, it has no problem establishing in freshwater due to its ability to tolerate a broad range of salinities and adapt quickly (Henderson and Bamber 1987, Leonardos and Sinis 2000). It is thermophilous, therefore its ability to survive the winters of the Great Lakes is limited (den Hartog and van der Velde 1987, Henderson and Bamber 1987). *Atherina boyeri* exhibits a rapid growth rate, early maturity, and frequent spawning over a long breeding season (Fernández-Delgado et al. 1988). Its reproductive strategy may contribute to its establishment if introduced to the Great Lakes.

Atherina boyeri can adapt to new environments rapidly. It established as a nonnative fish in Lake Ĕgirdir within 2 years of its introduction (Küçük et al. 2007). *Atherina boyeri* is capable of reaching high densities; it became a dominant fish in the community, comprising of nearly 50% of the ichthyofauna composition in the Mala Neretva estuary (Sršen 1995). The construction of levees in the Neretva River estuary changed the environment in a way that benefitted *Atherina boyeri* populations. *Atherina boyeri* is established in the Netherlands after intentional introduction, but its distribution is bound to waters that receive thermal discharge from the cooling systems of power plants (den Hartog and van der Velde 1987).

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6

This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
	7

- Atherina boyeri *survives in euryhaline conditions (coastal and estuarine waters, lagoons, salt marshes, shallow brackish, and inland waters) (Leonardos and Sinis 2000). Furthermore, it can tolerate a wide range of salinities from freshwater to hypersaline conditions (110% maximum recorded) (Henderson and Bamber 1987).*
- *This species can tolerate temperatures of 6-25˚C (Henderson and Bamber 1987).*
- *Juveniles have no abiotic preferences (Pombo 2005).*
- *It is capable of adapting rapidly, perhaps due to the great variety in longevity, reproductive years, size at maturity, and maximum size attributed to this species (Henderson and Bamber 1987, Küçük et al. 2012).*

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9
Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
	3

- *In general, fish from Ponto-Caspian have been able to invade Great Lakes (Ojaveer et al. 2002).*
- *This species can tolerate temperatures of 6-25˚C (Henderson and Bamber 1987).*
- *The northern range of this species is limited by the amount of fat the young can lay down (Henderson and Bamber 1987).*
- *It is thermophilous and may not be able to tolerate low temperatures, especially as juvenile fish (den Hartog and van der Velde 1987, Henderson and Bamber 1987).*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
	8

- Atherina boyeri *is an opportunistic feeder on zooplankton and benthic invertebrates, including copepods, cladocerans, gammarid amphipods, mysids and cumaceans, decapod larvae, insects, and eggs (Bartuloviç et al. 2004). Its diet changes with the seasons and prey availability.*
- *In typical coastal ecosystems, it preys on zooplankton, while in lagoons and estuaries it feeds on benthic organisms (Kiener and Spillman 1969, Trabelsi et al. 1994). Certain studies show that it feeds mainly on*

zooplankton and only secondarily on benthic organisms (Rosecchi and Crivelli 1992), while others have found a preference for benthic prey (Scipiloti 1998).

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	0
Unknown	U
	5

- Atheria boyeri *probably starts to face intense interspecific competition for food in autumn. Specialized predation of* A. boyeri *on fish larvae, especially in autumn, is likely an ecological adaptation of this species against food limitation. Through this behavior,* A. boyeri *would reduce inter- and intra-specific competition by removing a number of competitors that utilize the same food sources and thus raise its energy gains for overwintering by consuming food of higher nutrient value (Doulka et al. 2013). However, the level of inter-specific competition has not been tested in this ecosystem.*
- *Fish fry of* Economidichthys trichonis *and* Atherina boyeri *were found in* A. boyeri *stomach contents (Doulka et al. 2013). Larvae of* Economidichtys trichonis *and* A. boyeri *feed on zooplankton crustaceans, so they may compete with each other for food.* Economidichthys trichonis *is endemic to lakes Trichonis and Lysimachia and is threatened and* A. boyeri *may negatively impact its survival by preying on its larvae. However, the competitive abilities of* A. boyeri *have not been specifically studied.*

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
	3

- Atherina boyeri *has a high growth rate, early maturity, frequent spawning over a long breeding season, and greatly reduced longevity (Fernández-Delgado et al. 1988).*
- *This species develops to its full external adult morphology within 2 months of hatching, and reach sexual maturity within their first year of life (Henderson and Bamber 1987).*
- *This species reproduces in the summer with an average fecundity is 110.4 per individual, or a relative fecundity of 29.05 eggs per g of fish (Küçük et al. 2012).*

- Atherina presbyter *has an average relative fecundity of 49.2 eggs per g of fish (Moreno et al. 2005).* Atherina presbyter *has a higher relative fecundity than* A. boyeri*.*

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
	6

- *Becoming mature in their first year,* A. boyeri *forms dominant populations due to its abilities to quickly adapt and reproduce in inland waters (Küçük et al. 2012).*

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- *There is a history of successful Ponto-Caspian fish introductions in Great Lakes (Ojaveer et al. 2002).*
- *Models predict that* Atherina boyeri *has a potential to establish in Great Lakes if it is introduced (Kolar and Lodge 2002).*
- *The Ponto-Caspian (Caspian, Azov, and Black Seas) have similar climate and surface water temperature ranges as the Great Lakes (Grigorovich et al. 2003, Reid and Orlova 2002, USEPA 2008).*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- *Abiotic factors and climatic conditions of the native and introduced ranges of* Atherina boyeri *are quite similar to the Great Lakes, making the region compatible (Grigorovich et al. 2003, Reid and Orlova 2002).*
- *There is a history of successful Ponto-Caspian fish introductions in Great Lakes (Ojaveer et al. 2002).*
- Atherina boyeri *has a potential to establish in Great Lakes if it is introduced (Kolar and Lodge 2002).Great Lakes underwent similar anthropogenic eutrophication as the Ponto-Caspian region (Reid and Orlova 2002). Surface water temperature is similar between the Great Lakes and Ponto-Caspian seas (Grigorovich et al. 2003, Reid and Orlova 2002, USEPA 2008).*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0
Unknown	U
	8

- *In lakes, this species is pelagic, preferring still or slow-flowing waters (IUCN 2008a).*
- *It occurs in estuarine and coastal environments (Henderson and Bamber 1987), lagoons, salt marshes, shallow brackish water ecosystems, and inland waters (Leonardos and Sinis 2000). It has been found in freshwater lakes (Doulka et al. 2013).*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0
Unknown	U

	9

- *This species is found in waters that range from 7.6-26.7°C, so* A. boyeri *tolerates warm waters (Pombo 2005).*
- *The northern range of this species is limited by the amount of fat the young can lay down (Henderson and Bamber 1987); thus, warmer water temperatures and shorter duration of ice cover may benefit this species and/or facilitate this species' establishment in the Great Lakes.*
- *It is likely that salinization of the Great Lakes due to climate change will not greatly impact* A. boyeri *due to its ability to tolerate hypersaline waters (Henderson and Bamber 1987, Leonardos and Sinis 2000). This species may tolerate salinization better than freshwater fish native to the Great Lakes.*

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
	9

- Atherina boyeri *is an opportunistic feeder on zooplankton and benthic invertebrates, including copepods, cladocerans, gammarid amphipods, mysids and cumaceans, decapod larvae, insects, and eggs (Bartuloviç et al. 2004). Its carnivorous diet can also include worms, mollusks, and fish larvae (Quignard and Pras 1986).*
- *In typical coastal ecosystems, it preys on zooplankton, while in lagoons and estuaries it feeds on benthic organisms (Kiener and Spillman 1969, Trabelsi et al. 1994). Certain studies show that it feeds mainly on zooplankton and only secondarily on benthic organisms (Rosecchi and Crivelli 1992), while others have found a preference for benthic prey (Scipiloti 1998).*

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in	0

the Great Lakes but is likely to be introduced	
Yes, but the critical species (or one that may provide a similar function) is not present in the Great Lakes and is not likely to be introduced	-80% total points (at end)
Unknown	U
	9

- Atherina boyeri *lacks a species critical to its survival.*

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes)	6
Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0
Unknown	U
	0

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0
Unknown	U

U

- Atherina boyeri *is preyed on by carnivorous fish such as* Sphyraena *(Kalogirou et al. 2012).* Sphyraena *does not occur in the Great Lakes, but other piscivores do. It is unknown if piscivores in the Great Lakes would prey on* A. boyeri.

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9
Frequent, moderate inocula	6
Frequent, small inocula OR infrequent, large inocula	3
Infrequent, small or moderate inocula	0
Unknown	U
	U

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
	5

- Atherina boyeri *forms dominant populations due to its abilities to quickly adapt and reproduce in inland waters. It is considered a potential threat to lentic ecosystems. At the present, it is a common invading exotic fish species throughout Turkey (Küçük et al. 2007).*
- Atherina boyeri *has become dominant in fish communities of the Mala Neretva estuary (Sršen 1995) and Lake Trichonis (Doulka et al. 2013).*
- Atherina boyeri *was interntionally introduced to the Netherlands and became established, but its distribution is restricted to waters that receive thermal discharge from the cooling systems of power plants (den Hartog and van der Velde 1987).*
- *Its occurrence has been recorded in Sapanca Lake (Geldiay and Balik 1996), Güzelhisar Stream, Köyceğiz Lake (Balik 1979), Küçükçekmece Lake (Altun 1999), Lake İznik (Özeren 2004), Homa Lagoon (Sezen 2005), Hirfanlı Dam Lake, Beysehir Lake, and Mogan Lake (Innal and Erk'akan 2006), Turkey.*
- *It has been reported to occur in the Aral Sea and Lake Trasimeno (Freyhof and Kottelat 2008a).*

- *This species has been naturally introduced into Lake Trichonis in Western Greece, via moving from the sea to the lake through river channels. It is dominant in the fish community.*

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
	6

- *The species established in Lake Ĕgirdir in Turkey within 2 years of introduction (Küçük et al. 2012).*

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing the establishment and spread of this species)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent the establishment and/or spread of this species	0
Unknown	U
	0

- *There are no control methods within the Great Lakes specific to preventing the establishment or spread of this species.*

Establishment Potential Scorecard				
Points	**Probability for Establishment**	A. Total Points (pre-adjustment)		94
>100	High	**Adjustments**		
		B. Critical species	A*(1- 0%)	94
51-99	Moderate	C. Natural enemy	B*(1- 0%)	94

		Control measures	C*(1- 0%)	94
0-50	Low	**Potential for Establishment**		Moderate
# of questions answered as "unable to determine"	**Confidence Level**			
0-1	High	Total # of questions unknown		2
2-5	Moderate			
6-9	Low	Confidence Level		Moderate
>9	Very low			

Section C: Potential for Impact

IMPACT POTENTIAL RESULTS

Environmental: Moderate

Socio-Economic: Low

Beneficial: High

***Atherina boyeri* has the potential for moderate environmental impact if introduced to the Great Lakes.**

Atherina boyeri is a carrier of the metacercariae of *Labratrema minimus*, a parasitic trematode that also infects gobies (Combes 2001).

In some cases, *Atherina boyeri* dominates the fish community where introduced. In the Mala Neretva esuary, *Atherina boyeri* reached high densities to the point where it made up 50% of the fish composition (Sršen 1995). It is considered as a potential threat to lentic ecoystems (Küçük et al. 2007).

There is little or no evidence to support that *Atherina boyeri* has the potential for significant socio-economic impact if introduced to the Great Lakes.

It has not been reported that *Atherina boyeri* poses a threat to human health or water quality. There is no evidence that this species negatively impacts infrastructure, economic sectors, recreational activities and associated tourism, or the aesthetic appeal of the areas it inhabits.

***Atherina boyeri* has the potential for high beneficial effects if introduced to the Great Lakes.**

Increased population size of *Atherina boyeri* in the Neretva River estuary enhanced the production of the local fishery and the stock of sea bass *Dicentrarchu labrax* (Küçük et al. 2007). In Greece, it is sold for about United States $3 per kg and is edible (El-Sahn et al. 1990, Leonardos and Sinis 2000).

Introduction of *Atherina boyeri* may positively impact the populations of Great Lakes predatory fish and enhance recreational fishing. If *Atherina boyeri* were introduced, the parasitic trematode that it carries may infect invasive gobies of the Great Lakes and help decrease their populations.

POTENTIAL ENVIRONMENTAL IMPACT

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1 √
Not significantly	0
Unknown	U

- Atherina boyeri *harbors the metacercariae of the parasitic trematode* Labratrema minimus*, which also infects gobies (Combes 2001).*

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1 √
Not significantly	0
Unknown	U

- *Fish fry of* Economidichthys trichonis *and* Atherina boyeri *were found in* A. boyeri *stomach contents (Doulka et al. 2013). Larvae of* E. trichonis *and* A. boyeri *feed on zooplankton crustaceans, so they may compete with each other for food. Economidichthys trichonis is endemic to lakes Trichonis and Lysimachia and is threatened and* A. boyeri *may negatively impact its survival by preying on its larvae. However, the competitive abilities of* A. boyeri *have not been specifically studied.*
- Atheria boyeri *probably starts to face intense interspecific competition for food in autumn. Specialized predation of* A. boyeri *on fish larvae, especially in autumn, is likely an ecological adaptation of this species against food limitation. Through this behavior,* A. boyeri *would reduce inter- and intra-specific competition by removing a number of competitors that utilize the same food sources and thus raise its energy gains for overwintering by consuming food of higher nutrient value (Doulka et al. 2013).*
- *Forming dominant populations due to its abilities to quickly adapt and reproduce in inland waters,* A. boyeri *is considered a potential threat to lentic ecosystems (Küçük et al. 2007).*
- *In some cases,* Atherina boyeri *dominates the fish community where introduced. In the Mala Neretva esuary, A. boyeri reached high densities to the point where it made up 50% of the fish composition (Sršen 1995). It is considered as a potential threat to lentic ecoystems (Küçük et al. 2007).*

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of	6

one or more native populations, creation of a dead end or any other significant alteration in the food web)	
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	1
Not significantly	0
Unknown	U √

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0
Unknown	U √

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1
Not significantly	0
Unknown	U √

E6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1
Not significantly	0
Unknown	U √

Environmental Impact Total	**2**

Total Unknowns (U)	**4**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	**<u>Moderate</u>**
0	0-1	Low
1	0	
0	≥2	Unknown
1	≥1	

POTENTIAL SOCIO-ECONOMIC IMPACT

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1
Not significantly	0 √
Unknown	U

S2) Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1
Not significantly	0 √
Unknown	U

S3) Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0 √
Unknown	U

S4) Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

Socio-Economic Impact Total	**0**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**<u>Low</u>**
1	0	
0	≥2	Unknown
1	≥1	

<u>POTENTIAL BENEFICIAL EFFECT</u>

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1
Not significantly	0 √
Unknown	U

- *No data were found in this regard.*

B2) Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?

Yes, it is economically important to at least one of these industries	6 √
Yes, but its economic contribution is small	1
Not significantly	0
Unknown	U

- *Following introduction, this species adapted to Egirdir Lake (Turkey) in a relatively short period (within 2 years) and commercial fishing began in 2005 (Küçük et al. 2007).*
- *Beside its direct commercial importance, this species plays an important role in estuarine food web (Bartuloviç et al. 2004).*
- *Increased population size of* Atherina boyeri *in the Neretva River estuary enhanced the production of the local fishery and the stock of sea bass Dicentrarchu labrax (Küçük et al. 2007). In Greece, it is sold for about United States $3 per kg and is edible (El-Sahn et al. 1990, Leonardos and Sinis 2000).*

B3) Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local communities and/or tourism	6
It is sometimes employed recreationally, but adds little value to local communities or tourism	1
Not significantly	0 √
Unknown	U

- *No data were found in this regard.*

B4) Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR It is potentially important to medicine or research and is currently being or scheduled to be studied	1
Not significantly	0 √
Unknown	U

- *No data were found in this regard.*

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1
Not significantly	0 √
Unknown	U

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1
Not significantly	0 √
Unknown	U

Beneficial Effect Total	**6**
Total Unknowns (U)	**0**

Scoring		
Score	# U	**Impact**
>5	Any	**<u>High</u>**
2-5	Any	Moderate
0	0-1	Low
1	0	
0	≥2	Unknown
1	≥1	

Scientific Name: *Babko gymnotrachelus*
Kessler, 1857

Common Name: Racer Goby

Synonyms:

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: Unlikely

Hitchhiking/fouling: Unlikely

Unauthorized intentional release: Unlikely

Stocking/planting/escape from recreational culture: Unlikely

Escape from commercial culture: Unlikely

Transoceanic shipping: Moderate

***Babka gymnotrachelus* has a moderate probability of introduction to the Great Lakes (Confidence level: Moderate).**

Potential pathway(s) of introduction: Transoceanic shipping (ballast water)

Babka gymnotrachelus currently does not occur near waters connected to the Great Lakes basin. It produces sticky eggs (Kottelat and Freyhof 2007); however, it is unknown whether the eggs can foul vessels and survive transoceanic transport. This species is not stocked, commercially cultured, or sold in the Great Lakes region.

This species is present in ports that are in direct trade with the Great Lakes (NBIC). Adults can survive transport in ships (Kottelat and Freyhof 2007). Other species of gobies have been introduced outside their native range via shipping and ballast water: Round Goby (*Neogobius melanostomus*), Freshwater Tubenose Goby (*Proterorhinus marmoratus*), Monkey Goby (*Neogobius fluviatilis*), and Bighead Goby (*Neogobius kessleri*) (MacIsaac et al. 2001, Neilson and Stepien 2009a, Stepien and Tumeo 2006). Ballast water exchange using full strength sea water for 48 hours will result in 100% mortality of *Babka gymnotrachelus* (Ellis and MacIsaac 2009). Ballast water exchange requires filling ballast tanks with full strength sea water for 5 days; ballast water exchange regulations may prevent introduction of *Babka gymnotrachelus*. *Babka gymnotrachelus* may be introduced to the Great Lakes via ships declaring "No Ballast on Board" (NOBOB), which are exempt from ballast water exchange. The majority of ships entering the Great Lakes are NOBOB vessels and 43% of these ships contain residual water with less than 10‰ salinity (Johengen et al. 2005). In the study, the temperature of the residual water from the vessels sampled ranged from -0.7 to 23.9°C; thus *Babka gymnotrachelus* is likely to survive the salinity and temperature of the NOBOB ballast water.

Babka gymnotrachelus is native to the Ponto-Caspian basin and is also found in the Danube, Dniester, and the Bug rivers (Pinchuk et al. 2003). The Main-Danube Canal is one of the main dispersal routes for invasive Ponto-Caspian species to move into Central Europe (Leuven et al. 2009). It is currently expanding its range into Eastern, Central, and Western European waters (Borcherding et al. 2011, Haertl et al. 2012, Kalchhauser et al. 2013), and has reached the Baltic Sea (Danilkiewicz 1998). Its increased distribution in Europe has been attributed to canal construction and shipping (Kalchhauser et al. 2013).

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100
No, this species does not occur near waters connected to the Great Lakes basin and/or is not mobile or able to be transported by wind or water.	0 √
Unknown	U

- Babka gymnotrachelus *is not currently found in North America.*
- Babka gymnotrachelus *is native to the fresh and slightly brackish (oligo- to meso-haline) waters of the Black, Azov (Pinchuk et al. 2003, Stepien and Tumeo 2006, Svetovidov 1964), Caspian, Aral (Neilson and Stepien 2009), and Marmara seas (Stepien and Tumeo 2006), and the lower courses of Ponto-Caspian region rivers (Pinchuk et al. 2003, Polaçik et al. 2009), including the lower Danube and its tributaries and connected lakes (Pinchuk et al. 2003), the Dniester and its tributaries (Bodareu 1993, Smirnov 1986), the southern Bug (Grabowska and Grabowski 2005), the Dnieper (Bilko 1968, Borcherding et al. 2011, Pinchuk et al. 2003, Smirnov 1986, Ulman 1967), and the Don (Borcherding et al. 2011).*
- *It has been spreading throughout eastern, central, and western European waters (Borcherding et al. 2011, Haertl et al. 2012, Kalchhauser et al. 2013, Kottelat and Freyhof 2007), both longitudinally and northward (Harka and Biró 2007), and it has reached the Baltic Sea basin (Danilkiewicz 1998).*
- *This species prefers more stagnant waters (Kakareko et al. 2009) and littoral areas (Eros et al. 2005) in rivers, lakes, reservoirs, estuaries, coastal lagoons, backwaters, and industrial harbors (Kalchhauser et al. 2013, Kottelat and Freyhof 2007, Wiesner 2005) in at least Austria (Ahnelt et al. 2001, Wiesner 2005), Belarus (Rizevsky et al. 2007, Semenchenko et al. 2009), Bulgaria (Dikov and Zivkov 2004, Polaçik et al. 2008), Georgia (Ninua and Japoshvili 2008), Germany (Borcherding et al. 2011, Brandner et al. 2013, Freyhof 2003, Haertl et al. 2012), Hungary (Eros et al. 2005, Guti 2006), Poland (Feldheim et al. 2009, Grabowska and Grabowski 2005, Grabowska et al. 2010, Kakareko et al. 2009, Kvach and Mierzejewska 2011, Witkowski and Grabowska 2012), Romania (Bănărescu 1964, Borcea 1934), Serbia (Brown 2009, Guti 2006, Jurajda et al. 2005, Simonovic et al. 2006), Slovakia (Jurajda et al. 2005, Kautman 2001, Koščo et al. 2010 Ohayon and Stepien 2007), Turkey (Gaygusuz et al. 2007, Keskin 2010, Özulug et al. 2007, Tarkan et al. 2006), and Ukraine (Feldheim et al. 2009, Ohayon and Stepien 2007).*
- *Ohayon and Stepien (2007) suggest that based on the neogobiin traits of lacking a larval stage and a swimbladder (Pinchuk 1991),* B. gymnotrachelus *has low natural dispersal abilities.*

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75

This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0
Unknown	U √

- *Grabowska (2005) suggests that hull fouling is a possible reason, along with ballast water transport, for the relatively rapid expansion of Racer Goby range and other gobiid ranges in Europe.*
- Babka gymnotrachelus *has a pelvis that is fused to form a suction organ (Kottelat and Freyhof 2007), but it is unclear whether or not this suction organ would allow the racer goby to hitchhike on (foul) a vessel for long distances.*
- Babka gymnotrachelus *produces adhesive eggs which develop attached to stones, shells, and aquatic plants (Kottelat and Freyhof 2007); it is unclear whether or not this adhesion would allow Racer Goby eggs to hitchhike on (foul) a vessel for long distances.*

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1 √
Unknown	U

- Babka gymnotrachelus *is not currently found in North America.*

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a) Is this species sold at aquarium/pet/garden stores ("brick & mortar" or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100
No, this species this species is rarely/never sold.	0 √
Unknown	U

- Babka gymnotrachelus *is a fish that is not available for purchase from any source, and there is no documentation of availability within the Great Lakes region (see complete reference list as lack of evidence for potential introduction via unauthorized intentional release).*

- *Harka and Biró (2007) mention the aquarium industry being a potential introduction pathway for Ponto-Caspian gobies in general. They indiscriminately cite as sources for that note and other material the following references: Ahnelt et al. 1998, Biró 1972, Guti 1999, Guti 2000, Lusk et al. 2000, Holčík 2003.*
- *In concert, this information supports that* B. gymnotrachelus *is no more than rarely sold and only within its native range as opposed to within the Great Lakes region.*

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0 √
Unknown	U

- *Harka and Biró (2007) state that* B. gymnotrachelus *is not the object of recreational fisheries.*
- *Koščo et al. (2010) report that* B. gymnotrachelus *was stocked in Slovakian waters from a source in the Danube delta; no details on the reason(s) for the stocking are provided.*

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is <u>likely</u> to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces), this activity <u>may</u> occur within 20 km of the basin because of the species' popularity/value.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100
No, this species is not commercially cultured in or transported through the Great Lakes region.	0 √
Unknown	U

- *Harka and Biró (2007) state that* B. gymnotrachelus *is not the object of commercial fisheries.*

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80 √
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40
No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0
Unknown	U

- Babka gymnotrachelus *adults or eggs are known to be transportable via shipping (Kottelat and Freyhof 2007).*
- Babka gymnotrachelus *dispersal in Europe has also been facilitated by shipping, in addition to shipping canal construction (Kalchhauser et al. 2013).*
- *Related taxa have been introduced via shipping/ballast water; these include the Round (*Neogobius melanostomus*) and Freshwater Tubenose (*Proterorhinus marmoratus*) Gobies (MacIsaac et al. 2001, Neilson and Stepien 2009a, Stepien and Tumeo 2006), as well as the Monkey (*Neogobius fluviatilis*) and the Bighead (*Neogobius kessleri*) Gobies (Neilson and Stepien 2009a).*
- *Additionally, it has been suggested that avoiding ballast water collection during the nocturnally pelagic feeding*

of gobiids may further reduce their introduction to non-native waters (Hayden and Miner 2009).

- *Despite regulations and suggestions, Racer Goby spread has been rapid within Europe (Grabowska et al. 2010, Karlson et al. 2007, Ohayon and Stepien 2007), though in this region the introduction facilitation effects of channelization are difficult to segregate from those of shipping/ballast water.*
- *Hensler and Jude (2007) and Kornis et al. (2012) have proposed that Racer Goby uptake into ballast water is attributable to the nocturnally pelagic gobiid feeding strategy which results in Gobies rising in the water column during the night to feed.*
- *However, current ballast water exchange (BWE) regulations require ballast tanks to be filled with ocean water for approximately five days; since ocean waters have salinities of around 35 ppt and since Round Goby has a 100% mortality rate to two-day exposure to 30 ppt salinity conditions, it is predicted that these regulations may prevent further Round Goby inoculations (Ellis and MacIssac 2009).*
- *Current BWE practices are not perfect at eliminating freshwater species from ballast water, and they are reported to have not slowed the rate of species introduction into the Great Lakes (Ricciardi and MacIsaac 2008, Vander Zanden et al. 2010). Kornis et al. (2010) indicate that improvement to ballast regulation is needed to defend against further species introductions into the Great Lakes.*

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5 √
Yes, but this species has neither been observed in ballast/fouling ships entering the Great Lakes nor in ports in direct trade with the Great Lakes.	Score x 0.1
No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0
Unknown	U

- *It has been spreading in and into eastern, central, and western European waters (Borcherding et al. 2011, Haertl et al. 2012, Kalchhauser et al. 2013, Kottelat and Freyhof 2007), both horizontally and northward (Harka and Biró 2007), and has reached the Baltic Sea basin (Danilkiewicz 1998).*
- *It has been recorded to prefer more stagnant waters (Kakareko et al. 2009) and littoral areas (Eros et al. 2005) in rivers, lakes, reservoirs, estuaries, coastal lagoons, backwaters, and industrial harbors (Kalchhauser et al. 2013, Kottelat and Freyhof 2007, Wiesner 2005) in at least Austria (Ahnelt et al. 2001, Wiesner 2005), Belarus (Rizevsky et al. 2007, Semenchenko et al. 2009), Bulgaria (Dikov and Zivkov 2004, Polaçik et al. 2008), Georgia (Ninua and Japoshvili 2008), Germany (Borcherding et al. 2011, Brandner et al. 2013, Freyhof 2003, Haertl et al. 2012), Hungary (Eros et al. 2005, Guti 2006), Poland (Feldheim et al. 2009, Grabowska and Grabowski 2005, Grabowska et al. 2010, Kakareko et al. 2009, Kvach and Mierzejewska 2011, Witkowski and Grabowska 2012), Romania (Bănărescu 1964, Borcea 1934), Serbia (Brown 2009, Guti 2006, Jurajda et al. 2005, Simonovic et al. 2006), Slovakia (Kautman 2001, Koščo et al. 2010, Jurajda et al. 2005, Ohayon and Stepien 2007), Turkey (Gaygusuz et al. 2007, Keskin 2010, Özulug et al. 2007, Tarkan et al. 2006), and Ukraine (Feldheim et al. 2009, Ohayon and Stepien 2007).*

Vector Potential Scorecard					
Vector		**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind		**0**	x	**0**	Unlikely
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.		**U**	x 0.1	**U**	Unlikely
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)		**0**	x	**0**	Unlikely
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)		**0**	x	**0**	Unlikely
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)		**0**	x	**0**	Unlikely
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling		**80**	x 0.5	**40**	Moderate
Total Unknowns (U)	**1**	**Confidence Level**		Moderate	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

ESTABLISHMENT POTENTIAL RESULTS

Status: **Not established in North America, including the Great Lakes**

***Babka gymnotrachelus* has a high probability of establishment if introduced to the Great Lakes (Confidence level: Moderate).**

The native and introduced ranges of *Babka gymnontrachelus* have similar climatic and abiotic conditions as the Great Lakes (Grigorovich et al. 2003, Reid and Orlova 2002, USEPA 2008). This species occurs in waters where there is ice cover in the winter and can tolerate low oxygen levels (Charlebois et al. 1997, Reid and Orlova 2002); it is likely capable of overwintering in the Great Lakes. *Babka gymnotrachelus* feeds on soft-bodied invertebrates, which are common in the waters of the Great Lakes. Its establishment may be aided by the presence of Ponto-Caspian amphipods that are part of its diet (Grabowska and Grabowski 2005). It exhibits an extended spawning period and parental investment, which may facilitate the establishment of a self-sustaining population (Grabowska 2005). The models of Kolar and Lodge (2002) predict that *Babka gymnotrachelus* will quickly establish in the Great Lakes if introduced based on growth rate, tolerance ranges for temperature and salinity, history of invasiveness, and diet. Altered streamflow patterns and warming waters attributed to climate change may render the Great Lakes more similar to the Ponto-Caspian environment.

In a feeding experiment, *Babka gymnotrachelus* exhibited aggressive behavior towards *Cottus gobio*, a European bullhead experiencing declining populations (Kakareko et al. 2013). *Babka gymnotrachelus* obtained food more quickly than *Cottus gobio*, and displaced it from the feeding area. *Babka gymnotrachelus* may have a competitive advantage over non-aggressive fish when foraging. If introduced to the Great Lakes, *Babka gymnotrachelus* may compete with fish that forage for invertebrates during the night. There is a great level of dietary overlap between *Babka gymnotrachelus* and native percid fish in the Danube River (Copp et al. 2008). However, in some cases, *Babka gymnotrachelus* avoids resource competition with native fish due to dissimilar foraging habits; in the Baltic Sea, this species exhibits spatial segregation while foraging to avoid competition with native fish (Grabowska and Grabowski 2005, Kakareko et al. 2003). The opportunistic feeding strategy of *Babka gymnotrachelus* may aid its establishment.

Although the presence of some species in the Great Lakes, such as Ponto-Caspian amphipods, may facilitate the establishment of *Babka gymnotrachelus*, the presence of other species may do the opposite. The round goby, a Ponto-Caspian fish that has established in the Great Lakes, is more aggressive than *Babka gymnotrachelus* and may deter its establishment (Charlebois et al. 1997).

Babka gymnotrachelus may expand its range after introduction. It has moved from its native range and spread into the Danube River via the Main-Danube Canal (Haertl et al. 2012). This species has exhibited spontaneous range expansion from the Danube delta to waters in Slovakia (Koščo et al. 2010). This species expanded its range 70-100 km upstream in one year, from the Danube to the Polsko Kosovo of the Yantra River (Vassilev et al. 2008). In the Yantra River, *Babka gymnotrachelus* was the 2nd most abundant and 2nd most frequently found Ponto-Caspian gobiid. *Babka gymnotrachelus* invades habitats with disturbed temperature and flow regimes, such as waters altered by hydropower dams and power plant outlets (Harka and Bíró 2007, Kalchhauser et al. 2013).

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-	9

saturated), AND nutrient (oligotrophic-eutrophic) levels.	
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
	7

- *Vilizzi and Copp (2012) report the climatic requirements of* B. gymnotrachelus *as temperate.*
- Babka gymnotrachelus *is native to fresh and slightly brackish (oligo- to mesohaline) waters (within Pinchuk et al. 2003). Kornis et al. (2012) report a salinity tolerance range for the related Round Goby as <30 ppt.*
- Babka gymnotrachelus *is routinely compared in the scientific literature as similar to the Round Goby,* Neogobius melanostomus*; the Round Goby is noted to be tolerant of a wide range of environmental conditions (Charlebois et al. 1997, Jude 2001), having a thermal tolerance range of -1 to 30°C (Moskal'kova 1996) and a critical lethal dissolved oxygen threshold of between 0.4 and 1.3 mg/L (Charlebois et al. 1997), though it is known to migrate from hypoxic conditions of <4 mg/L (Arend et al. 2011).*
- *Ponto-Caspian species in general are noted to have great adaptive capacities and tolerance to elevated water salinity (Ahnelt et al. 1998, Charlebois et al. 1997, Reid and Orlova 2002).*
- Babka gymnotrachelus *is noted to preferentially invade habitats with disturbed temperature and flow regimes, such as those altered by hydropower dams and power plant outlets which both warm and calm the waters (Harka and Biró 2007, Kalchhauser et al. 2013).*
- *Kolar and Lodge (2002) report that* B. gymnotrachelus *is predicted by both of their models, which incorporated five habitat needs parameters, to become established in the Great Lakes if introduced.*
- *Vilizzi and Copp (2012) report that* B. gymnotrachelus *has a high-risk FISK (Fish Invasiveness Scoring Kit) score for the United Kingdom.*
- *Tolerances of* B. gymnotrachelus *to other listed factors were not found in this literature review.*

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9
Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
	8

- *Vilizzi and Copp (2012) report the climatic requirements of* B. gymnotrachelus *as temperate.*
- Babka gymnotrachelus *is routinely compared in the scientific literature as similar to the Round Goby,* Neogobius melanostomus*; the Round Goby is noted to be tolerant of a wide range of environmental conditions (Charlebois et al. 1997, Jude 2001); Round Goby is documented to have a thermal tolerance range of -1 to 30°C (Moskal'kova 1996) and a critical lethal dissolved oxygen threshold of between 0.4 and 1.3 mg/L (Charlebois et al. 1997), though it is known to migrate from hypoxic conditions of <4 mg/L (Arend et al. 2011).*
- *Ponto-Caspian species in general are noted to have great adaptive capacities (Ahnelt et al. 1998, Charlebois et al. 1997, Reid and Orlova 2002).*
- Babka gymnotrachelus *is noted to preferentially invade habitats with disturbed temperature and flow regimes*

such as those altered by hydropower dams and power plant outlets which both warm and still the waters (Harka and Biró 2007, Kalchhauser et al. 2013).

- *Kolar and Lodge (2002) report that* B. gymnotrachelus *is predicted by both of their models, which incorporated five habitat needs parameters, to become established in the Great Lakes if introduced.*
- *Vilizzi and Copp (2012) report that* B. gymnotrachelus *has a high-risk FISK (fish Invasiveness Scoring Kit) score for the United Kingdom.*
- *Related gobiid taxa have been introduced to and have established in Great Lakes waters; these include the Round (*Neogobius melanostomus*) and Tubenose (*Proterorhinus marmoratus*) Gobies, as well as the Monkey (*Neogobius fluviatilis*) and the Bighead (*Neogobius kessleri*) Gobies (MacIsaac et al. 2001, Neilson and Stepien 2009a, Stepien and Tumeo 2006).*
- *Tolerances of* B. gymnotrachelus *to other listed factors were not found in this literature review.*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
	9

- *The broad benthivorous diet of* B. gymnotrachelus *in its native habitat consists of Polychaeta, Oligochaeta, Mollusca, Crustacea, Chironomidae larvae, fish eggs, small fishes (both larvae and juveniles), macrophytes, and algae (Gaygusuz et al. 2007, Grabowska and Grabowski 2005, Pinchuk et al. 2003, Smirnov 1986), and it exhibits an opportunistic foraging strategy and feeding plasticity (Grabowska and Grabowski 2005, Jaroszewska et al. 2008, Kakareko et al. 2005).*
- *Its opportunistic feeding strategy may aid its establishment (Grabowska and Grabowski 2005)*

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	0
Unknown	U
	1

- *One of the potential interactions between invasive Racer Gobies and native Great Lakes species is competition for food (Holčík 1991). Though invasive fishes often compete for food with native fishes and eat their eggs and young (Witkowski and Grabowska 2012), in the Baltic basin, Racer Goby has been documented to avoid* *resource competition with native percid populations via spatial segregation during foraging (Grabowska and Grabowski 2005, Kakareko et al. 2003). Conversely, high dietary overlap was found between Racer Goby and native percid fishes in the Danube (Copp et al. 2008).*

- *In the Polish section of the Vistula River, racer gobies have been found to be predators of epifauna and zoobenthos, though negative impacts of invasive racer gobies to native species and ecosystem function have not yet been researched (Kakareko et al. 2005).*
- *Polaçik et al. (2008) note that Racer Goby is smaller and more delicate than are either Round Goby or Bighead Goby; Round Goby has been documented to be more aggressive than the Racer goby and to drive the Racer Goby to marginal interstitial areas (Polaçik et al. 2008).*
- *Though Kolar and Lodge (2002) have predicted based on results of multiple models that Racer Goby spread will be fast in the Great Lakes, it is typically rare relative to other Ponto-Caspian gobiid species, such as Round and Bighead Goby (Jurajda et al. 2005, Kovac et al. 2009, Ohayon and Stepien 2007). Round Goby has been found to typically have higher distribution and abundance than even Bighead Goby (Copp et al. 2005, Jurajda et al. 2005, Kovac et al. 2009), and phylogenetically, Racer Goby is more closely related to Bighead Goby than the other three Ponto-Caspian gobiids present already in the Great Lakes (Simonovic 1999). Further, Kakereko et al. (2009) found low abundance (2.5%) of Racer Goby even when Round Goby and Bighead Goby were absent from the invaded Polish Vistula River, and Ondračková et al. (2005, 2012) report that Racer Goby had not become abundant in the upper Danube despite its presence there for nearly a decade.*
- *In the Great Lakes region, round goby is currently the dominant Ponto-Caspian goby, and it is one of the most abundant benthic fish in the Great Lakes (Charlebois et al. 1997, Holčík 1991, Jude 1997, Jude 2001). Racer Goby may not obtain high density and distribution in the Great Lakes due to pre-established Round Goby dominance.*

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
	6

- *Racer Gobies live four to five years in total and become sexually mature at about two years of age, producing small, adhesive eggs during multiple spawning periods which begin relatively early (April) in the spring (Bilko 1968, Kottelat and Freyhof 2007) and can last into August making their reproductive period relatively long (Grabowska 2005).*
- *Racer Gobies have been documented to have the smallest eggs among four early-spring spawning gobiid species in their native range (Bilko 1968).*

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self-fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding	6

establishment in the Great Lakes based on these attributes)	
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
	9

- *Racer Gobies live four to five years in total and become sexually mature at about two years of age, producing small, adhesive eggs during multiple spawning periods which begin relatively early (April) in the spring (Bilko 1968, Kottelat and Freyhof 2007) and can last into August making their reproductive period relatively long (Grabowska 2005). Such an extended spawning period has been suggested to increase the likelihood of an invading species successfully establishing even despite unfavorable conditions (Grabowska 2005).*
- *Males also exhibit nest-guarding behavior until eggs hatch approximately two-weeks after their laying, and this parental care may augment establishment (Grabowska 2005).*
- *Invading Gobies tend to have other traits of altricial life history that may increase their invasion success, notably early maturation and increased fecundity (Grabowska 2005, Kovac et al. 2009, L'avrinčíková et al. 2005, L'avrinčíková and Kovac 2007). In fact, invasive Racer Goby populations have demonstrated earlier maturation than their native counterparts (Grabowska 2005, L'avrinčíková et al. 2005); this same pattern has been observed for Round Gobies in both its non-native Danubian and Detroit River ranges (L'avrinčíková and Kovac 2007, MacInnis and Corkum 2000) as well as for Bighead Gobies in the non-native Slovak stretch of the Danube (Kovac et al. 2009).*
- Babka gymnotrachelus *exhibits an extended spawning period and parental investment, which may facilitate the establishment of a self-sustaining population (Grabowska 2005).*
- *Racer Gobies have been documented to have the smallest eggs among four early-spring spawning gobiid species in their native range (Bilko 1968).*
- *Kolar and Lodge (2002) incorporated thirteen life-history characteristics into their models of Ponto-Caspian fish invasion including growth rates and egg size; their models both predict that Racer Goby will establish and quickly spread.*

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- *Vilizzi and Copp (2012) report the climatic requirements of* B. gymnotrachelus *as temperate to north temperate, which is the climatic condition in both the Ponto-Caspian and the Great Lakes regions (Simberloff and Rejmanek 2011).*
- Babka gymnotrachelus *is routinely compared in the scientific literature as similar to the Round Goby,* Neogobius melanostomus*; however, the Round Goby is noted to be tolerant of a wide range of environmental*

conditions (Charlebois et al. 1997, Jude 2001).

- *Kolar and Lodge (2002) report that* B. gymnotrachelus *is predicted by both of their models, which incorporated five habitat needs parameters, to become established in the Great Lakes if introduced, further suggesting climatic similarity between the Ponto-Caspian and Great Lakes regions.*
- *The Ponto-Caspian (Caspian, Azov, and Black Seas) have similar climate and surface water temperature ranges as the Great Lakes (USEPA 2008, Grigorovich et al. 2003, Reid and Orlova 2002).*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- Babka gymnotrachelus *is noted to preferentially invade habitats with disturbed temperature and flow regimes such as those altered by hydropower dams and power plant outlets which both warm and still the waters (Harka and Biró 2007, Kalchhauser et al. 2013); the related species Round Goby is documented to have a thermal tolerance range of -1 to 30°C (Moskal'kova 1996) and the information provided in this assessment suggests that the thermal range for the Great Lakes region is somewhere within the broad range of 0 to 30°C. The information provided in the assessment also suggests that successfully invasive fish to the Great Lakes will be able to tolerate temperatures of <5°C, which is at the lower end of theRound Goby's tolerance.*
- *Ponto-Caspian species in general are noted to have great adaptive capacities (Ahnelt et al. 1998, Charlebois et al. 1997, Reid and Orlova 2002).*
- *Kolar and Lodge (2002) report that* B. gymnotrachelus *is predicted by both of their models, which incorporated five habitat needs parameters, to become established in the Great Lakes if introduced, further suggesting abiotic factor similarity between the Ponto-Caspian and Great Lakes regions.*
- Babka gymnotrachelus *is routinely compared in the scientific literature as similar to the Round Goby,* Neogobius melanostomus*; however, the Round Goby is noted to be tolerant of a wide range of environmental conditions (Charlebois et al. 1997, Jude 2001).*
- *Great Lakes underwent similar anthropogenic eutrophication as the Ponto-Caspian region (Reid and Orlova 2002). Surface water temperature is similar between the Great Lakes and Ponto-Caspian seas (Grigorovich et al. 2003, Reid and Orlova 2002, USEPA 2008).*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0
Unknown	U

	6

- *In its native range, Racer Goby typically inhabits soft-bottomed river reaches with silt-clay, sand, gravel, or silt-clay-sand sediments (Azizova 1962, Haertl et al. 2012) including soft-bottomed backwaters (Haertl et al. 2012, Kottelat and Freyhof 2007); it often exploits areas overgrown with aquatic vegetation for both refuge and foraging (Kakareko et al. 2005, Smirnov 1986).*
- *However, Round Goby typically inhabits coastal shallows with stony, sandy, or dreissenid shell covered grounds as well as areas with silty-sand or softer, well-vegetated substrates (Pinchuk et al. 2003). Due to the overlaps in the habitat descriptions of these two species, and that the Round Goby has already established in all five Great Lakes, the Great Lakes habitats available to Racer Goby invasion are likely suitable for its survival, development, and reproduction.*
- *Kolar and Lodge (2002) report that* B. gymnotrachelus *is predicted by both of their models, which incorporated five habitat needs parameters, to become established in the Great Lakes if introduced, further suggesting habitat similarity between the Ponto-Caspian and Great Lakes regions and therefore habitat suitability within the Great Lakes for invading racer goby.*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0
Unknown	U
	6

- *Due to warming from global climate change, we can expect the Great Lakes may improve as potential habitat for Ponto-Caspian gobiids (Harko and Biró 2007); northward range expansions of Ponto-Caspian gobiids and other fishes have been observed in Europe, and these have been posited as attributable to warming trends.*
- Babka gymnotrachelus *is noted to preferentially invade habitats with disturbed temperature and flow regimes such as those altered by hydropower dams and power plant outlets which both warm and still the waters (Harka and Biró 2007, Kalchhauser et al. 2013).*
- Babka gymnotrachelus *is native to fresh and slightly brackish (oligo- to mesohaline) waters (Pinchuk et al. 2003).*
- *Ponto-Caspian species in general are noted to have great adaptive capacities and tolerance to elevated water salinity (Ahnelt et al. 1998, Charlebois et al. 1997, Reid and Orlova 2002). Salt pollution of freshwaters has been noted to facilitate gobiid invasions (Kottelat and Freyhof 2007). This may give Racer Goby (and other gobies) an advantage in utilization of Great Lakes waters as habitat.*
- Babka gymnotrachelus *is routinely compared in the scientific literature as similar to the Round Goby,* Neogobius melanostomus*; the Round Goby is noted to be tolerant of a wide range of environmental conditions (Charlebois et al. 1997, Jude 2001), and Ponto-Caspian species in general are noted to have great adaptive capacities (Ahnelt et al. 1998, Charlebois et al. 1997, Reid and Orlova 2002).*
- *Ability of* B. gymnotrachelus *to adapt to or benefit from other listed effects of climate change on the Great Lakes freshwater ecosystem was not uncovered in this literature review.*

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
	9

- *The broad benthivorous diet of* B. gymnotrachelus *in its native habitat consists of Polychaeta, Oligochaeta, Mollusca, Crustacea, Chironomidae larvae, fish eggs, small fishes (both larvae and juveniles), macrophytes, and algae (Gaygusuz et al. 2007, Grabowska and Grabowski 2005, Pinchuk et al. 2003, Smirnov 1986), and it exhibits an opportunistic foraging strategy and feeding plasticity (Grabowska and Grabowski 2005, Jaroszewska et al. 2008, Kakareko et al. 2005).*
- *The Racer Goby is known to eat dreissenid mussels, which also invaded the Great Lakes from the Ponto-Caspian region (Gaygusuz et al. 2007). In the study done by Gaygusuz et al. (2007), the dresissenid mussels only made a small proportion of the Racer Goby's diet.*

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Great Lakes and is not likely to be introduced	-80% total points (at end)
Unknown	U
	9

- *A dependency of Racer Goby on some other critical species was not uncovered in this literature review.*

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes)	6
Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0
Unknown	U
	7

- *Racer Goby, similarly to Round Goby, is known to eat dreissenid mussels, which also invaded the Great Lakes from the Ponto-Caspian region (Gaygusuz et al. 2007). Dreissenid mussels are widespread and abundant in the Great Lakes, and they are a preferred food item of Gobies in general in areas in which the mussels are abundant. In the study done by Gaygusuz et al. (2007),* Babka gymnnotrachelus *was studied in the waters with high dreissenid abundance, and the mussels comprised 4% of its diet.*
- *Grabowska and Grabowski (2005) mention that the presence of Ponto-Caspian amphipods may facilitate the establishment of* Babka gymnotrachelus*, which feeds on invertebrates. There are several Ponto-Caspian amphipods that occur in the Great Lakes.*
- *Ray and Corkum (1997) found that only Round Gobies larger than 7 cm in length could eat dreissenids; presumably a similar size threshold occurs for racer gobies. Larger Racer Gobies may incorporate these dreissenid mussels into their diet. Specific predictions of dreissenid mussels promoting the establishment of Racer Goby and specific reports of dreissenid mussels aiding the establishment of Racer Goby in other areas were not uncovered in this literature review, though such facilitation is suggested (Corkum et al. 2004, Gaygusuz et al. 2007).*

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in	-10% total points (at

native ranges OR this natural enemy has low abundance in the Great Lakes)	end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0
Unknown	U
	U

- *In both its native region and in the Great Lakes, Round Gobies are prey items of several obligate benthivores, facultative benthivores, and even some pelagic fishes (Corkum et al. 2004). In the Great Lakes regions, these Round Goby predators include Smallmouth Bass (*Micropterus dolomieu*), Stonecat (*Noturus flavus*), Burbot (*Lota lota*), and Yellow Perch (*Perca flavens*) as well as Freshwater Drum (*Aplodinotus grunniens*), Walleye (*Stizostedion vitreum*), and Lake Sturgeon (*Acipenser fulvescens*) (Corkum et al. 2004). Racer Gobies may be expected to be prey for these same species in the Great Lakes, though the literature review conducted for this assessment did not uncover data as to how effectively this predation might control an invading racer goby population.*
- *Racer Gobies are known hosts for several European parasites including: the trematode* Cryptocotyle concavum *and the acanthocephalan* Pseudoechinorhynchus *(Najdenova 1974, Smirnov 1986), the monogenean* Gyrodactylus proterorhini *(Mierzejewska et al. 2011, Mierzejewska et al. 2012), the digenean* Bucephalus polymorphus *(Kvach and Mierzejewska 2011), the ciliate* Trichodina domerguei *(Mierzejewska 2007), and others (Ondračková et al. 2012).*
- *Invading populations of Racer Gobies have been documented to have lower parasite species richness than is the case for populations in their native range (Ondračková et al. 2012); similar findings exist for Round Gobies (Corkum et al. 2004). Pronin et al. (1997) notes that low parasite loads are also found in Great Lakes populations of* Dreissena polymorpha*, a primary food source for Great Lakes gobies.*
- *Kvach and Stepien (2008) note that North American parasites seem poorly adapted to use gobiids as hosts.*
- *The distributions of the previously named parasites, specifically their presences in the Great Lakes, were not uncovered in this literature review. Additionally, Great Lakes native species that can serve as hosts for known parasites of racer goby were not uncovered in this literature review. Finally, little was uncovered in this literature review as to which if any North American parasites can infect invading Racer Goby populations. Therefore, the role of parasites in Racer Goby establishment and spread is unclear.*

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9
Frequent, moderate inocula	6
Frequent, small inocula OR infrequent, large inocula	3
Infrequent, small or moderate inocula	0
Unknown	U
	U

- *Both the Round and Tubenose Goby populations across the Great Lakes have been documented to have high genetic diversity similar to those in their native ranges; this suggests that low/no founder effects were experienced by these invading populations and that instead both invasions were the result of introductions of many diverse individuals, either via large inocula or frequent small inocula (Brown and Stepien 2009, Stepien and Tumeo 2006). Additionally, Round Goby population comparisons between Lake St. Clair and Lake Eire reveal significant genetic differences suggestive of separate founding events and thus frequent inocula (Dillon and Stepien 2001).*
- *Similar results have been discovered for genetic variation of dreissenid mussel populations in the Great Lakes,*

giving further support to that the numbers of introduction events of species transported in ballast water from the Ponto-Caspian region are, or were at least at one point, high (Stepien et al. 2002, Stepien and Tumeo 2006).

- *To a greater extent than has been observed for the Great Lakes, invading goby populations throughout Europe tend to have lower genetic diversity than is the case for populations in their native region (Stepien and Tumeo 2006); this makes sense considering the ability of Gobies to migrate via connected waterways, which tends to produce founder effects, at least over the short term. However, Round Goby invasion of the Baltic Sea has also been reported to be via multiple inoculations (Kornis et al. 2012).*
- *Not enough information was uncovered in this literature review to determine accurately either the frequency or size of racer goby inoculation.*

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
	5

- *Racer Goby has been spreading in and into eastern, central, and western European waters (Borcherding et al. 2011, Haertl et al. 2012, Kalchhauser et al. 2013, Kottelat and Freyhof 2007), both horizontally and northward (Harka and Biró 2007), and it has reached the Baltic Sea basin (Danilkiewicz 1998).*
- *Based on the information above, while racer goby has not spread beyond Europe at this time, it has spread into the Baltic Sea drainage basin from the Ponto-Caspian basin. Based on this, its spread to a new but proximate drainage basin may be characterized as a semi-wide distribution.*

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
	9

- *Kolar and Lodge (2002) report that* B. gymnotrachelus *is predicted by both of their models to become* *established in the Great Lakes if introduced and to have a fast rate of spread.*

- *Racer Goby spread around Europe has been reported to be occurring at an "explosive" rate over the past decade; this same rapid spread rate has been attributed to Round Goby (Grabowska et al. 2010, Karlson et al. 2007). Other studies have similarly reported the Racer Goby (Ohayon and Stepien 2007) and Round Goby (Harka and Biró 2007) spread rates in Europe to be quick over about the past two decades.*

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing the establishment and spread of this species)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent the establishment and/or spread of this species	0
Unknown	U
	U

- *Chemicals targeting benthic fishes have been used to attempt to control Round Goby population size and thus spread ability in the Great Lakes (Schreier et al. 2008). Trapping using Round Goby specific pheromones and commercial exploitation of Round Goby for fish meal and oil markets have also been proposed as potential control measures (Corkum et al. 2008, Kornis et al. 2012). It is unknown if these control strategies would be effective against the related racer goby.*

<table>
<tr><th colspan="5">Establishment Potential Scorecard</th></tr>
<tr><td>Points</td><td>Probability for Establishment</td><td colspan="2">A. Total Points (pre-adjustment)</td><td>107</td></tr>
<tr><td rowspan="2">>100</td><td rowspan="2">High</td><td colspan="2">Adjustments</td><td></td></tr>
<tr><td>B. Critical species</td><td>A*(1- 0%)</td><td>107</td></tr>
<tr><td rowspan="2">51-99</td><td rowspan="2">Moderate</td><td>C. Natural enemy</td><td>B*(1- 0%)</td><td>107</td></tr>
<tr><td>Control measures</td><td>C*(1- 0%)</td><td>107</td></tr>
<tr><td>0-50</td><td>Low</td><td colspan="2">Potential for Establishment</td><td>High</td></tr>
<tr><td># of questions answered as “unable to determine”</td><td>Confidence Level</td><td colspan="3"></td></tr>
</table>

0-1	High	Total # of questions unknown	3
2-5	Moderate		
6-9	Low	Confidence Level	Moderate
>9	Very low		

Section C: Potential for Impact

IMPACT POTENTIAL RESULTS

Environmental: Unknown

Socio-Economic: Low

Beneficial: Unknown

Current research on the potential for environmental impacts to result from *Babka gymnotrachelus* if introduced to the Great Lakes is inadequate to support proper assessment.

Babka gymnotrachelus feeds on dreissenid mussels that may contain toxins and ingests sediment that act as sinks for contaminants while foraging in benthic environments. These ingested contaminants may undergo biomagnification at higher trophic levels, but there is not enough evidence to conclude whether this would occur if *Babka gymnotrachelus* were introduced to the Great Lakes.

Babka gymnotrachelus is a host for several European parasites including the trematode *Cryptocotyle concavum*, the acanthocephalan *Pseudoechinorhynchus* (Najdenova 1974, Smirnov 1986), the monogenean *Gyrodactylus proterorhini*, the digenean *Bucephalus polymorphus*, and the ciliate *Trichodina domerguei* (Kvach and Mierzejewska 2011, Mierzejewska et al. 2011, Mierzejewska et al. 2012, Mierzejewska et al. 2014). *Dreissena polymorpha* is an intermediate host for *Bucephalus polymorphus* and are eaten by Gobies. Pike and Perch that prey on Gobies may be infected. Evidence suggest that populations of Racer Gobies and Round Gobies that are introduced outside their native ranges have lower parasite species richness than in their native ranges (Corkum et al. 2004, Ondračková et al. 2012). In the Great Lakes, *Dreissena polymorpha* exhibits low parasite loads (Pronin et al. 1997).

If introduced, *Babka gymnotrachelus* may compete with native Great Lakes species for food (Holčík 1991). As a non-native fish in the Danube River, *Babka gymnotrachelus* exhibits a strong dietary overlap with some native fishes (Copp et al. 2008). In a laboratory experiment, *Babka gymnotrachelus* exhibited competitive and aggressive behavior towards *Cottus gobio* when feeding (Kakareko et al. 2013). *Cottus bairdi*, a similar cottid species, is present in the Great Lakes; however there is insufficient evidence to conclude whether *Babka gymnotrachelus* would outcompete *Cottus bairdi* if introduced to the Great Lakes. In the Baltic basin, *Babka gymnotrachelus* avoids resource competition with native fishes through spatial segregation while foraging (Grabowska and Grabowski 2005, Kakareko et al. 2003). *Babka gymnotrachelus* exhibits opportunistic feeding habits and plasticity (Grabowska and Grabowski 2005). Thus, it is not clear whether *Babka gymnotrachelus* would outcompete native species if introduced to the Great Lakes.

Babka gymnotrachelus can potentially be preyed on by Great Lakes fishes if introduced; however, there is not enough research to determine if this species has the potential to alter predator-prey relationships. The round goby *Neogobius melanstomus* has altered food web structure in the Great Lakes (Corkum et al. 2004).

Dreissenids are native to the Ponto-Caspian and increased water clarity and altered nutrient cycling regimes (Qualls et al. 2007). If *Babka gymnotrachelus* feeds on a substantial amount of dreissenid mussels, water clarity and nutrient cycling regimes may be impacted, but it is unknown whether this impact is positive or negative.

There is little or no evidence to support that *Babka gymnotrachelus* has the potential for significant socio-economic impacts if introduced to the Great Lakes.

It has not been reported that *Babka gymnotrachelus* poses a threat to water quality. There is no evidence that this species negatively impacts infrastructure, economic sectors, recreational activities and associated tourism, or the aesthetic appeal of the areas it inhabits.

While foraging in benthic environments, *Babka gymnotrachelus* ingests sediments that are a sink for contaminants. *Babka gymnotrachelus* feeds on dreissenid musssels and may result in the bioaccumulation of contaminants to higher trophic levels (Kornis et al. 2012). However, the link between *Babka gymnotrachelus* and bioaccumulation of toxins has not been demonstrated.

Current research on the potential for beneficial impacts to result from *Babka gymnotrachelus* if introduced to the Great Lakes is inadequate to support proper assessment.

Babka gymnotrachelus feed on the invasive dreissenid mussels (Gaygusuz et al. 2007), but its ability as an effective biological control agent is unknown. This fish is not commercially valuable and is an insignificant part of the fishing industry in the Caspian basin (Azizova 1962, Pinchuk et al. 2003). *Babka gymnotrachelus* is not recreationally or medically valuable. It has not been indicated that *Babka gymnotrachelus* can be used to improve water quality. It does not have significant positive ecological impacts.

POTENTIAL ENVIRONMENTAL IMPACT

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1
Not significantly	0
Unknown	U √

- *As a benthivore, Racer Goby ingests sediment, and toxins deposited in sediments are therefore also ingested by these fish; Goby consumption of dreissenids has also been suggested to facilitate bioaccumulation of contaminants to upper food web levels (Kornis et al. 2012). The toxins accumulated by the Racer and other Gobies are transferred up the food chain when they are eaten by larger fish, birds, or water snakes (Corkum et al. 2004, Kornis et al. 2012).*
- *Racer Gobies are known hosts for several European parasites including the trematode* Cryptocotyle concavum *and the acanthocephalan* Pseudoechinorhynchus *(Najdenova 1974, Smirnov 1986), the monogenean* Gyrodactylus proterorhini *(Mierzejewska et al. 2011, Mierzejewska et al. 2012), the digenean* Bucephalus

polymorphus *(Kvach and Mierzejewska 2011), the ciliate* Trichodina domerguei *(Mierzejewska 2007), and others (Ondračková et al. 2012).*

- Bucephalus polymorphus *also uses* Dreissena polymorpha *as a host for the early components of its life cycle, and these mussels are the source of its cercariae, which infect the Gobies (Kvach and Mierzejewska 2011); Gobies eaten by Pike or Perch carry the parasite to them, its definitive hosts (Kvach and Mierzejewska 2011). Racer goby presence could facilitate the infection of pike and/or perch in Great Lakes waters.*
- *Invading populations of racer gobies have been documented to have lower parasite species richness than is the case for populations in their native range (Ondračková et al. 2012); similar findings exist for round gobies (Corkum et al. 2004). Pronin et al. (1997) notes that low parasite loads are also found in Great Lakes populations of* Dreissena polymorpha*, a primary food source for Great Lakes gobies.*
- *The distributions of the previously named parasites, specifically their presences in the Great Lakes, were not uncovered in this literature review. Additionally, Great Lakes native species that can serve as hosts for known parasites of Racer Goby were not uncovered in this literature review. Therefore, the role of Racer Goby in non-indigenous parasite introduction, establishment, and spread within the Great Lakes is unclear.*

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1
Not significantly	0
Unknown	U √

- *One of the potential interactions between invasive Racer Gobies and native Great Lakes species is competition for food (Holčík 1991);* B. gymnotrachelus *in its native habitat has a broad benthivorous diet which consists of Polychaeta, Oligochaeta, Mollusca, Crustacea, Chironomidae larvae, fish eggs, small fishes (both larvae and juveniles), macrophytes, and algae (Gaygusuz et al. 2007, Grabowska and Grabowski 2005, Pinchuk et al. 2003, Smirnov 1986), and it exhibits an opportunistic foraging strategy and feeding plasticity (Grabowska and Grabowski 2005, Jaroszewska et al. 2008, Kakareko et al. 2005).*
- *Though invasive fishes often compete for food with native fishes and eat their eggs and young (Witkowski and Grabowska 2012), in the Baltic basin, Racer Goby has been documented to avoid resource competition with native percid populations via spatial segregation during foraging (Grabowska and Grabowski 2005, Kakareko et al. 2003).*
- *Conversely, high dietary overlap was found between Racer Goby and native percid fishes in the Danube (Copp et al. 2008). In the Polish section of the Vistula River, Racer Goby has been found to be a predator of epifauna and zoobenthos, though negative impacts of invasive Racer Gobies to native species and ecosystem function have not yet been researched (Kakareko et al. 2005).*
- *In the Great Lakes, the related species Round Goby has been linked to the decline of native Great Lakes fish including several Sculpin, Darters, and Perch (Corkum et al. 2004, Jude et al. 1995, Kornis et al. 2012). The declines have been documented to be due to Round Gobies eating native fish larvae and fry (Chotkowski and Marsden 1999, Corkum et al. 2004) as well as interfering with native fish spawning and displacement through habitat competition (Dubs and Corkum 1996, Janssen and Jude 2001, Kornis et al. 2012).*
- *In a laboratory experiment,* Babka gymnotrachelus *exhibited competitive and aggressive behavior towards* Cottus gobio *when feeding (Kakareko et al. 2013).* Cottus bairdi*, a similar cottid species, is present in the Great Lakes; however, there is insufficient evidence to conclude whether* Babka gymnotrachelus *would outcompete* Cottus bairdi *if introduced to the Great Lakes.*

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in the food web)	6
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	1
Not significantly	0
Unknown	U √

- *Round Goby invasion has resulted in alterations to food web structure via diet shifts among Goby predators (Corkum et al. 2004). In both its native region and in the Great Lakes, Round Gobies are prey items of several obligate benthivores, facultative benthivores, and even some pelagic fishes (Corkum et al. 2004). In the Great Lakes regions, these Round Goby predators include Smallmouth Bass (*Micropterus dolomieu*), Stonecat (*Noturus flavus*), Burbot (*Lota lota*), and Yellow Perch (*Perca flavens*) as well as Freshwater Drum (*Aplodinotus grunniens*), Walleye (*Stizostedion vitreum*), and Lake Sturgeon (*Acipenser fulvescens*) (Corkum et al. 2004). Racer Gobies may be expected to be prey for these same species in the Great Lakes, though the literature review conducted for this assessment did not uncover data as to the potential food web impacts of an invading racer goby population.*

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0
Unknown	U √

- *No documentation of Racer or Round Gobies having genetic effects on native populations was uncovered in this literature review; see the complete reference list as lack of evidence for such an impact.*

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1
Not significantly	0
Unknown	U √

- *Racer Goby is known to eat dreissenid mussels, which also invaded the Great Lakes from the Ponto-Caspian region (Gaygusuz et al. 2007). Dreissenid mussels are widespread and abundant in the Great Lakes, and, though few native organisms eat them, they are a preferred food item of gobies in general (the study specifically included racer goby among the studied goby species) in areas in which the mussels are abundant (Gaygusuz et al. 2007). As dreissenid mussels have impacted Great Lakes water clarity and nutrient cycling regimes (Hecky* *et al. 2004, Johengen et al. 1995, Karatayev et al. 2002, Leach 1993), Racer Goby addition to the Great Lakes has the potential to decrease dreissenid mussel abundance and therefore to impact water clarity and nutrient cycling regimes.*

E6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1
Not significantly	0
Unknown	U √

- Babka gymnotrachelus *in its native habitat has a broad benthivorous diet which consists of Polychaeta, Oligochaeta, Mollusca, Crustacea, Chironomidae larvae, fish eggs, small fishes (both larvae and juveniles), macrophytes, and algae (Gaygusuz et al. 2007, Grabowska and Grabowski 2005, Pinchuk et al. 2003, Smirnov 1986); since macrophytes and algae are among its food resources, it has the potential to alter macrophyte and phytoplankton communities.*

Environmental Impact Total	**0**
Total Unknowns (U)	**6**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	Low
1	0	
0	≥2	**Unknown**
1	≥1	

POTENTIAL SOCIO-ECONOMIC IMPACT

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1 √

Not significantly	0
Unknown	U

- *As a benthivore, Racer Goby ingests sediment; toxins deposited in sediments are therefore also ingested by these fish. Goby consumption of dreissenids has also been suggested to facilitate bioaccumulation of contaminants to upper food web levels (Kornis et al. 2012). The toxins accumulated by the Racer and other Gobies are transferred up the food chain when they are eaten by larger fish, birds, or water snakes (Corkum et al. 2004, Kornis et al. 2012). This feeding activity thereby has the ability to move contaminants formerly relatively sequestered in the sediments into food webs.*

S2) Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1
Not significantly	0 √
Unknown	U

- *No documentation of Racer Goby causing infrastructure damage effects was uncovered in this literature review; see the complete reference list as lack of evidence for such an impact.*

S3) Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0 √
Unknown	U

S4) Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

- *No specific documentation of Racer Goby inhibiting recreational activities and/or associated tourism in areas it inhabits was uncovered in this literature review; see the complete reference list as lack of evidence for such an impact.*

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

- *No specific documentation of Racer Goby altering perceptions of aesthetic or natural value of areas it inhabits was uncovered in this literature review; see the complete reference list as lack of evidence for such an impact.*

Socio-Economic Impact Total	**1**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**Low**
1	0	
0	≥2	Unknown
1	≥1	

POTENTIAL BENEFICIAL EFFECT

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1
Not significantly	0
Unknown	U √

- *Racer Goby is known to eat dreissenid mussels, which also invaded the Great Lakes from the Ponto-Caspian region (Gaygusuz et al. 2007). Dreissenid mussels are widespread and abundant in the Great Lakes, and, though few native organisms eat them, they are a preferred food item of gobies in general (the study specifically* *included Racer Goby among the studied Goby species) in areas in which the mussels are abundant (Gaygusuz et al. 2007). However, the ability of Racer Goby to act as an effective biological control agent is unknown.*

B2) Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?

Yes, it is economically important to at least one of these industries	6
Yes, but its economic contribution is small	1
Not significantly	0 √
Unknown	U

- *Pinchuk et al. (2003) states fishermen in the Dneister-Dniper estuaries dislike* B. gymnotrachelus *as a thin fish and thus it comprises <10% of the commercial Goby fishing industry in that area; similarly, low (<4%) representation is presented to exist for Caspian fisheries (Azizova 1962). No information is given here as to the representation of the Goby fishing industry as compared to the rest of the fishing industry.*
- *This information supports that* B. gymnotrachelus *is no more than rarely sold and only so within its native range as opposed to within the Great Lakes region; therefore, it is deemed not to be a commercially valuable species.*

B3) Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local communities and/or tourism	6
It is sometimes employed recreationally, but adds little value to local communities or tourism	1
Not significantly	0 √
Unknown	U

- *Harka and Biró (2007) mention the aquarium industry being a potential introduction pathway for Ponto-Caspian gobies in general. They indiscriminately cite as sources for that note and other material the following references: Ahnelt et al. 1998, Biró 1972, Guti 1999, Guti 2000, Lusk et al. 2000, Holčík 2003.*
- *No specific documentation of Racer Goby being of recreational value was uncovered in this literature review; see the complete reference list as lack of evidence for such an impact.*

B4) Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR It is potentially important to medicine or research and is currently being or scheduled to be studied	1
Not significantly	0 √
Unknown	U

- *No specific documentation of Racer Goby being of medicinal or research value was uncovered in this literature review; see the complete reference list as lack of evidence for such an impact.*

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1
Not significantly	0 √
Unknown	U

- *No specific documentation of Racer or Round Gobies removing toxins or pollutants from water columns or otherwise increasing water clarity was uncovered in this literature review; see the complete reference list as lack of evidence for such an impact.*

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1
Not significantly	0
Unknown	U √

- *Round Goby invasion has resulted in alterations to food web structure via diet shifts among Goby predators (Corkum et al. 2004). In both its native region and in the Great Lakes, Round Gobies are prey items of several obligate benthivores, facultative benthivores, and even some pelagic fishes (Corkum et al. 2004). In the Great Lakes regions, these Round Goby predators include Smallmouth Bass (*Micropterus dolomieu*), Stonecat (*Noturus flavus*), Burbot (*Lota lota*), and Yellow Perch (*Perca flavens*) as well as Freshwater Drum (*Aplodinotus grunniens*), Walleye (*Stizostedion vitreum*), and Lake Sturgeon (*Acipenser fulvescens*) (Corkum et al. 2004). Racer Gobies may be expected to be prey for these same species in the Great Lakes.*

Beneficial Effect Total	**0**
Total Unknowns (U)	**2**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	Low
1	0	Low
0	≥2	**Unknown**
1	≥1	**Unknown**

Scientific Name: *Benthophilus stellatus*
Sauvage, 1874

Common Name: Stellate Tadpole-Goby, Starry Goby

Synonyms:

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: Unlikely

Hitchhiking/fouling: Unlikely

Unauthorized intentional release: Unlikely

Stocking/planting/escape from recreational culture: Unlikely

Escape from commercial culture: Unlikely

Transoceanic shipping: Low

***Benthophilus stellatus* has a low probability of introduction to the Great Lakes (Confidence level: High).**

Potential pathway(s) of introduction: Transoceanic Shipping (ballast water)

Benthophilus stellatus does not currently occur near waters connected to the Great Lakes basin. This species is not known to hitchhike or foul. *Benthophilus stellatus* is not commercially cultured, stocked, or sold in the Great Lakes region. This species has neither been observed fouling or in ballasts of ships entering the Great Lakes or in ports in direct trade with the Great Lakes. This species has a temperature range of 4 - 20°C and can tolerate salinity levels up to 12 ppt (Kottelat and Freyhof 2007, Whitehead et al. 1986). Thus, ballast water exchange regulations that require filling ballast tanks with full-strength sea water may limit the introduction of this species to the Great Lakes. *Benthophilus stellatus* is predicted to be introduced to the Great Lakes via ballast water (Kolar and Lodge 2002, Ricciardi and Rasmussen 1998). *Benthophilus stellatus* may be introduced to the Great Lakes via ships declaring "No Ballast on Board" (NOBOB), which are exempt from ballast water exchange. The majority of ships entering the Great Lakes are NOBOB vessels and 43% of these ships contain residual water with less than 10‰ salinity (Johengen et al. 2005). In the study, the temperature of the residual water from the vessels sampled ranged from -0.7 to 23.9°C; thus *B. stellatus* is likely to survive the salinity and temperature of ballast water from most NOBOB vessels.

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100
No, this species does not occur near waters connected to the Great Lakes basin and/or is not mobile or able to be transported by wind or water.	0 √
Unknown	U

- *There is no record of* Benthophilus stellatus *occurring beyond the Black and Caspian basins (Neilson and Stepien 2009b).*

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0 √
Unknown	U

- *There is no relevant research regarding* Benthophilus stellatus's *hitchhiking or fouling ability.*

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a) Is this species sold at aquarium/pet/garden stores ("brick & mortar" or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100
No, this species this species is rarely/never sold.	0 √
Unknown	U

- *There is no mention in peer reviewed papers of* Benthophilus stellatus *having any commercial value. A thorough search of possible sales of this species for any means returned no results.*

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0 √
Unknown	U

- *There is no mention in peer reviewed papers of* Benthophilus stellatus *having any commercial value. A thorough search of possible stocking yielded no results.*

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is likely to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces), this activity may occur within 20 km of the basin because of the species' popularity/value.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100
No, this species is not commercially cultured in or transported through the Great Lakes region.	0 √
Unknown	U

- *There is no mention in peer reviewed papers of* Benthophilus stellatus *having any commercial value. A thorough search of possible culturing yielded no results.*

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80 √
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40
No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0
Unknown	U

- Benthophilus stellatus *has been shown to be tolerant of brackish water which could support the theory of it being transported through ballast water (Mordukhaĭ-Boltovskoĭ 1964).*

- Benthophilus stellatus *has been reported to have a temperature range of 4°C - 20°C, and tolerate salinity levels up to 12 ppt. This includes brackish water in shallow lagoons (Kottelat and Freyhof 2007, Whitehead et al. 1986). It has also been recorded in the coastal regions of seas where the dissolved oxygen levels ranged 8-10 mg/L (Snigirov et al. 2012).*
- *Ballast water exchange regulations that require filling ballast tanks with full-strength sea water (35 ppt salinity) may limit the introduction of this species to the Great Lakes.*
- Benthophilus stellatus *is predicted to be able to invade the Great Lakes in ballast water (Kolar and Lodge 2002, Ricciardi and Rassmussen 1998).*

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5
Yes, but this species has neither been observed in ballast/fouling ships entering the Great Lakes nor in ports in direct trade with the Great Lakes.	Score x 0.1 √
No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0
Unknown	U

- Benthophilus stellatus *is native to the Black Sea, Sea of Azov, and Caspian rivers and estuaries (e.g., Dniester). It also occurs in the Volga River and many middle Volga reservoirs (e.g., Kuybyshev, Saratov, Cheboksary) (Neilson and Stepien 2009b).*
- *In 2011, it was recorded for the first time in the upper Dnieper River basin in Belarus (Rizevsky et al. 2013).*
- *It is also present in the Kiev reservoir on the Dnieper River (Witkowski and Grabowska 2012).*
- Benthophilus stellatus *is not yet known to be in areas from which shipping traffic to the Great Lakes originates.*

Vector Potential Scorecard				
Vector	**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind	**0**	x	**0**	Unlikely
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.	**0**	x	**0**	Unlikely
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)	**0**	x	**0**	Unlikely
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)	**0**	x	**0**	Unlikely
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)	**0**	x	**0**	Unlikely

Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling	**80**	x 0.1	**8**	Low

Total Unknowns (U)	**0**	**Confidence Level**	High

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

ESTABLISHMENT POTENTIAL RESULTS

Status: **Not established in North America, including the Great Lakes**

***Benthophilus stellatus* has a moderate probability of establishment if introduced to the Great Lakes (Confidence level: High).**

The native and introduced ranges of *Benthophilus stellatus* have similar climatic and abiotic conditions as the Great Lakes (Grigorovich et al. 2003, Reid and Orlova 2002, USEPA 2008). There are various habitats throughout the Great Lakes basin that match the requirements of *Benthophilus stellatus* (Johengen et al. 2000). This species prefers waters that are colder and less saline; thus, increased water temperatures and salinization due to climate change may make the Great Lakes a less suitable environment for it. *Benthophilus stellatus* has a generalist diet and feeds on invertebrates and small fishes (Kottelat and Freyhof 2007, Whitehead et al. 1986). It is likely that *B. stellatus* will find an appropriate food source if introduced to the Great Lakes. The presence of nonindigenous crustaceans and small fishes from the Ponto-Caspian may aid its establishment, but not to a significant degree (USGS 2012). Large piscivorous fish may prey on *B. stellatus*. There is potential for predators to inhibit the establishment of this species; however, similar Gobies such as the Round Goby (*Neogobius melanostomus*) have established despite predation pressure (Kornis et al. 2013, Whitehead et al. 1986). Relative to Gobies within and outside of its subfamily, *B. stellatus* has an average fecundity (Whitehead et al. 1986).

Benthophilus stellatus has extended its range beyond the Ponto-Caspian basin. The construction of reservoirs has resulted in the introduction of *B. stellatus* to the Volga and Don Rivers (Ermolin 2010, Ivancheva and Ivanchev 2008, Luzhnyak and Korneev 2006). Once established in a region, it has spread moderately fast, accelerated by human activities. A year after its discovery, the abundance of *B. stellatus* was high (Yashanin 1982).

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
	6

- Benthophilus stellatus *has been reported to survive in temperatures of 4°C - 20°C, and salinity levels up to 12 ppt. This includes brackish water in shallow lagoons (Kottelat and Freyhof 2007, Whitehead et al. 1986). It has also been recorded in the coastal regions of seas where the dissolved oxygen levels ranged 8-10 mg/L (Snigirov et al. 2012).*

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9
Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
	7

- Benthophilus stellatus *has been shown to occur in waters that do reach 4°C and in deeper waters where light may not be abundant (Kottelat and Freyhof 2007, Whitehead et al. 1986). However, there is no record of it surviving in low dissolved oxygen levels*.

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0

Unknown	U
	8

- Benthophilus stellatus *has a benthic diet and feeds on mollusks, crustaceans, insect larvae, and small fishes (Kottelat and Freyhof 2007, Whitehead et al. 1986).*

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	0
Unknown	U
	4

- *There is no reported data on the competitive ability of* B. stellatus*. Although other species in family Gobiidae such as the Round Goby (*Neogobius melanostomus*) have outcompeted species outside of their natural range extensively (Kornis et al. 2013).*

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
	3

- Benthophilus stellatus *has an average fecundity when compared with other gobies within and outside of its subfamily (Whitehead et al. 1986).*

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self-fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes	9

based on these attributes)	
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
	0

- Benthophilus stellatus *possesses no known reproductive strategies that would aid in its establishment*.

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- *The seas and basins where* B. stellatus *naturally occurs has similar seasonality to that of the Great Lakes basin but is generally colder* (*Matishov et al. 2008)*.
- *The Ponto-Caspian (Caspian, Azov, and Black Seas) have similar climate and surface water temperature ranges as the Great Lakes (Grigorovich et al. 2003, Reid and Orlova 2002, USEPA 2008).*
- *The Great Lakes and Ponto-Caspian region are climatically compatible, which is one of the attributing factors to the success of Ponto-Caspian species in the Great Lakes (Reid and Orlova 2002).*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- Benthophilus stellatus *occurs in the streams and seas of the Black and Azov sea basins. It can occupy either brackish or fresh water with various substrates (Whitehead et al. 1986).*
- *Great Lakes underwent similar anthropogenic eutrophication as the Ponto-Caspian region (Reid and Orlova 2002). Surface water temperature is similar between the Great Lakes and Ponto-Caspian seas (Grigorovich et al. 2003, Reid and Orlova 2002, USEPA 2008).*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0
Unknown	U
	7

- *There are various habitats throughout the Great Lakes basin that match the requirements of* B. stellatus *(Johengen et al. 2000). It generally occupies muddy rivers and the shallow regions of lakes and seas with various substrates and water temperatures (Kottelat and Freyhof 2007, Whitehead et al. 1986). This species occupies similar habitat to that of the Round Goby (*Neogobius melanostomus*) which has spread throughout various Great Lakes basin habitats (Kornis et al. 2013).*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0
Unknown	U
	0

- Benthophilus stellatus *occupies water that is cool with low salinity (Kottelat and Freyhof 2007, Whitehead et al. 1986). While the Great Lakes ecosystem currently could possibly support it, any increase in water temperature or salinity would make the ecosystem less suitable.*

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
	9

- Benthophilus stellatus *is a generalist feeding on various benthic organisms, all of which are very prevalent throughout the Great Lakes (Kottelat and Freyhof 2007, Whitehead et al. 1986).*

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Great Lakes and is not likely to be introduced	-80% total points (at end)
Unknown	U
	9

- *There is no critical species required by* B. stellatus *at any life stage (Whitehead et al. 1986).*

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9

Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes)	6
Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0
Unknown	U
	1

- *Various species that are considered non-indigenous to the Great Lakes such as crustaceans and small fishes could serve as potential food sources for* B. stellatus *but they would not facilitate its spread any more than naturally occurring species (USGS 2012).*

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0
Unknown	U
	-20%

- *Being a small fish,* B. stellatus *could be targeted by any number of larger piscivorous fish as prey but most likely not preferentially or enough to stop its establishment in the Great Lakes basin.* Benthophilus stellatus *is similar in size and habitat selection to the Round Goby (*Neogobius melanostomus*), which has not been stopped by predation (Kornis et al. 2013, Whitehead et al. 1986).*

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9
Frequent, moderate inocula	6

Frequent, small inocula OR infrequent, large inocula	3
Infrequent, small or moderate inocula	0
Unknown	U
	U

- Benthophilus stellatus *has been identified as having the potential of being introduced through transoceanic shipping, but there have been no recorded cases of this actually happening (USEPA 2008).*

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
	4

- *There have been limited "invasions" of* B. stellatus *past its native range. It naturally occurs in various lakes, rivers, and seas throughout the Ponto-Caspian steppe (Whitehead et al. 1986). There have been documented reports of it spreading through the Volga and Don with the creation of reservoirs (Ermolin 2010, Luzhnyak and Korneev 2006, Ivancheva and Ivanchev 2008).*

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
	6

- Benthophilus stellatus *has spread into various tributaries and reservoirs near its natural occurrence. In the Saratov Reservoir, fish abundance increased from very low abundance in 1969-1985 to low abundance in 1986-1995 (low abundance maintained in 1996-2007) (Ermolin 2010). In the Saratov Reservoir, numbers increased from one individual caught in a fry trawl in 1974 to 146 individuals caught in 1976 (Ermolin 2010). In the middle stretch of the Oka River (Russia), abundance increased from rare in 1991-2000 to scarce in 2001-2006*

(Ivancheva and Ivanchev 2008). This spread has been accelerated by human activities such as the construction of reservoirs and dams.

- *A year after its discovery, the abundance of* Benthophilus stellatus *was high (Yashanin 1982).*

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing the establishment and spread of this species)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent the establishment and/or spread of this species	0
Unknown	U
	0

- *There have been no reported instances of introductions by transoceanic shipping, the proposed method for introduction into the Great Lakes. No methods known to prevent establishment or spread of this species are present in this ecosystem.*

Establishment Potential Scorecard				
Points	**Probability for Establishment**	A. Total Points (pre-adjustment)		80
>100	High	**Adjustments**		
		B. Critical species	A*(1- 0%)	80
51-99	Moderate	C. Natural enemy	B*(1- 20%)	64
		Control measures	C*(1- 0%)	64
0-50	Low	**Potential for Establishment**		Moderate
# of questions answered as "unable to determine"	**Confidence Level**			
0-1	High	Total # of questions unknown		1
2-5	Moderate			
6-9	Low	Confidence Level		High
>9	Very low			

Section C: Potential for Impact

IMPACT POTENTIAL RESULTS

Environmental: Unknown

Socio-Economic: Low

Beneficial: Low

Current research on the potential for environmental impacts to result from *Benthophilus stellatus* if introduced to the Great Lakes is inadequate to support proper assessment.

There is insufficient information available to determine whether *Benthophillus stellatus* poses a threat to other species or water quality. There are no reports on how it affects or interacts with other species. It is unknown whether this species alters the physical components of the ecosystem.

There is little or no evidence to support that *Benthophilus stellatus* has the potential for significant socio-economic impacts if introduced to the Great Lakes.

It has not been reported that *Benthophilus stellatus* poses a threat to human health or water quality. There is no evidence that this species negatively impacts infrastructure, economic sectors, recreational activities and associated tourism, or the aesthetic appeal of the areas it inhabits.

There is little or no evidence to support that *Benthophilus stellatus* has the potential for significant beneficial impacts if introduced to the Great Lakes.

It has not been indicated that *Benthophilus stellatus* can be used for the control of other organisms or improving water quality. Other gobies such as the Round Goby (*Neogobius melanostomus*) are known to eat nonindigenous dreissenid mussels that are invasive in the Great Lakes, and may reduce their populations somewhat (Baker and Li 2015). Dreissenid mussels are responsible for altering the water quality in the Great Lakes (Mida et al. 2010), so reducing their populations may also have an effect on water quality. However, there are no records suggesting that this particular species, *Benthophilus stellatus*, can act as a biological control agent for dreissenid mussels. There is no evidence to suggest that this species is commercially, recreationally, or medically valuable. Other Goby species are in the market for the aquaculture trade, but there are no records that suggest that *B. stellatus* is commercially valuable (Whitehead et al. 1986). It does not have significant positive ecological impacts.

POTENTIAL ENVIRONMENTAL IMPACT

NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1
Not significantly	0
Unknown	U √

- *There is no record of* Benthophilus stellatus *posing a hazard or threat to the health of native species.*

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1
Not significantly	0
Unknown	U √

- *The competitive abilities of* Benthophilus stellatus *are not well known.*

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in the food web)	6
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	1
Not significantly	0
Unknown	U √

- *There is no record of* B. stellatus *having an effect on predator prey relationships.*

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0 √
Unknown	U

- *There is no record of* B. stellatus *affecting native populations genetically.*

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1
Not significantly	0
Unknown	U √

- *There is no record of* B. stellatus *having an effect on water quality*.

E6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1
Not significantly	0
Unknown	U √

- *There is no record of* B. stellatus *having an effect on the physical components of the ecosystem*.

Environmental Impact Total	**0**
Total Unknowns (U)	**5**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	Low
1	0	Low
0	≥2	**Unknown**
1	≥1	**Unknown**

POTENTIAL SOCIO-ECONOMIC IMPACT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1
Not significantly	0 √
Unknown	U

- *There is no record of* B. stellatus *posing any threat to human health.*

S2) Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1
Not significantly	0 √
Unknown	U

- *There is no record of* B. stellatus *damaging infrastructure.*

S3) Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0 √
Unknown	U

- *There is no record of* B. stellatus *having an effect on the water quality.*

S4) Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

- *There is no record of* B. stellatus *having an effect on markets or economic sectors.*

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation	6

and tourism	
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

- *There is no record of* B. stellatus *inhibiting recreational activities.*

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

- *There is no record of* B. stellatus *diminishing the perceived aesthetic or natural value.*

Socio-Economic Impact Total	**0**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**Low**
1	0	
0	≥2	Unknown
1	≥1	

POTENTIAL BENEFICIAL EFFECT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular effect. An "Unknown" response is appropriate if the potential for a particular effect might be inferred but has not been explicitly reported or if there is an unresolved debate about a particular effect.

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1
Not significantly	0 √

Unknown	U

- *There is no record of* B. stellatus *acting as a biological control agent for non indigenous organisms. Other Goby species from similar regions with similar diets, such as the Round Goby (*Neogobious melanostomus*), have been speculated to curb nonindigenous mussel populations (Baker and Li 2015).*

S2) B2) Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?

Yes, it is economically important to at least one of these industries	6
Yes, but its economic contribution is small	1
Not significantly	0 √
Unknown	U

- *There is no record of* B. stellatus *being commercially valuable, although some markets do exist for larger Goby species and others are featured in the aquaculture trade (Whitehead et al. 1986).*

S3) B3) Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local communities and/or tourism	6
It is sometimes employed recreationally, but adds little value to local communities or tourism	1
Not significantly	0 √
Unknown	U

- *There is no record of* B. stellatus *having any recreational value.*

S4) B4) Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR It is potentially important to medicine or research and is currently being or scheduled to be studied	1
Not significantly	0 √
Unknown	U

- *There is no record of* B. stellatus *having any medical or research value.*

S5) B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1
Not significantly	0 √
Unknown	U

- *There is no record of* B. stellatus *having an effect on the water quality. Other Goby species from similar regions with similar diets, such as the Round Goby (*Neogobious melanostomus*), have been speculated to curb* *nonindigenous mussel populations (Baker and Li 2015). This affect on the mussel population could hypothetically alter water quality but probably not significantly*.

S6) B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1
Not significantly	0 √
Unknown	U

- *There is no record of* B. stellatus *having any ecological impact.*

Beneficial Effect Total	**0**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**Low**
1	0	
0	≥2	Unknown
1	≥1	

Scientific Name: *Carassius carassius*
Linnaeus, 1758

Common Name: Crucian Carp, Golden Carp, Gibele, Prussian Carp, English Carp

Synonyms:

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: Unlikely

Hitchhiking/fouling: Unlikely

Unauthorized intentional release: Low

Stocking/planting/escape from recreational culture: Unlikely

Escape from commercial culture: Unlikely

Transoceanic shipping: Unlikely

***Carassius carassius* has a low probability of introduction to the Great Lakes (Confidence level: High).**

Potential pathway of introduction: Unauthorized Intentional Release

Although Crucian Carp have been reported in in Illinois and Texas, these populations are considered possible misidentifications. Identification is difficult due to this species' similarity to Goldfish (*Carassius auratus*) and Common Carp (*Cyprinus carpio*) (USGS 2015). This species is farmed worldwide, and occasionally kept in water gardens. The similarity to other cyprinids increases the risk of accidental transportation or introduction.

While no negative impacts have been reported from Crucian Carp, other cyprinids have had negative impacts due to their broad environmental tolerance and diet.

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100
No, this species does not occur near waters connected to the Great Lakes basin and/or is not mobile or able to be transported by wind or water.	0 √
Unknown	U

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0 √
Unknown	U

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a) Is this species sold at aquarium/pet/garden stores ("brick & mortar" or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100 √
No, this species this species is rarely/never sold.	0
Unknown	U

- *Although Crucian Carp are available from aquarium stores online (e.g., from Cob House in the United Kingdom, or as "Gold Crucian Carp" from Kingworld Aquarium), they were not found for sale in the US.*
- *There is also a significant potential for misidentification (Tarkan et al. 2010) and sale of Crucian Carp as or with Goldfish (*Carassius auratus*).*

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1 √
Unknown	U

- *Fish identified as Crucian Carp have been found for sale only in the United Kingdom and Asia.*

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0 √
Unknown	U

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is likely to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces), this activity may occur within 20 km of the basin because of the species' popularity/value.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100
No, this species is not commercially cultured in or transported through the Great Lakes region.	0 √

Unknown	U

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40
No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0 √
Unknown	U

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5
Yes, but this species has neither been observed in ballast/fouling ships entering the Great Lakes nor in ports in direct trade with the Great Lakes.	Score x 0.1
No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0
Unknown	U

Vector Potential Scorecard				
Vector	**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind	**0**	x	**0**	Unlikely
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.	**0**	x	**0**	Unlikely
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)	**100**	x 0.1	**10**	Low
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)	**0**	x	**0**	Unlikely
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)	**0**	x	**0**	Unlikely
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling	**0**	x	**0**	Unlikely
Total Unknowns (U) **0**		**Confidence Level**	High	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

ESTABLISHMENT POTENTIAL RESULTS

Status: Not established in North America, including the Great Lakes

***Carassius carassius* has a moderate probability of establishment if introduced to the Great Lakes (Confidence level: High).**

Carassius carassius can survive in a wide variety of water conditions and are remarkably hardy. They are restricted to freshwater and are omnivores. This makes them a potential invader to the Great Lakes. *Carassius carassius* are an open substrate spawner with eggs that adhere to twigs and macrophytes (Holopainen et al. 1997) so they use aquatic weeds for spawning (egg attachment) (FAO 2013a). The Great Lakes region has many habitat types that would meet the requirements for *Carassius carassius* eggs to attach to.

This species spread occurs primarily through human release, which has been rapid due to confusing/mistaken taxonomic identification, as well as its common occurrence as a pet in Europe.

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
	7

- C. carassius *is remarkably hardy; they can live for hours out of water (Muus and Dahlstrom 1978).*
- *This species is tolerant of anoxic and very low oxygen conditions (Schofield et al. 2015).*
- *This species can tolerate water temperatures up to 38°C (Horoszewicz 1973).*
- *This species can tolerate pH of 4 (Holopainen and Ikari 1992).*
- *This species can survive in waters with temperatures below 0°C, and can even survive for several days with frozen integument (Schofield et al. 2013) or burrowed into mud (Holopainen et al. 1997).*
- C. carassius *is restricted to freshwater.*

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9
Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but	3

it is not known as an overwintering species)	
Unlikely	0
Unknown	U
	9

- C. carassius *is tolerant of anoxic and very low oxygen conditions (Schofield et al. 2013).*
- *This species can survive in waters with temperatures below 0°C, and can even survive for several days with frozen integument (Schofield et al. 2013) or burrowed into mud (Holopainen et al. 1997).*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
	9

- *This species is an omnivore that feeds on organic detritus, filamentous algae, small benthic animals, and pieces and seeds of aquatic weeds. The fry/larvae feed on zooplankton (FAO 2013a).*
- *Planktonic and benthic invertebrates form the dominant part of diet in all size classes; plant material, phytoplankon and detritus are also commonly found (Holopainen et al. 1997).*
- *Dominant items in this species' diet can vary, e.g., molluscs, chironomid larvae, or cladocera (Uspenskaja 1953).*

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	0
Unknown	U
	3

- *Smaller eutrophic lakes or nutrient-rich, vegetated bays may have considerable numbers of carp (Hamrin 1979), though not likely to dominate. This species does best in monospecific ponds (Holopainen et al. 1997).*

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
	3

- *Relative fecundity of* C. carassius *has been reported as 119.2 (Copp et al. 2010) and 129.2 (Holopainen et al. 1997).*
- *Relative fecundity for* Carassius auratus *has been reported at 251.7 (Copp et al. 2010) and 270 (Tarkan et al. 2010).*
- *Relative fecundity of* Carassius gibelio *has been reported at 78-251 (Leonardos et al. 2008).*

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
	0

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0

Unknown	U
	8

- *This species is native to local areas of England, but has spread throughout England as a result of introduction. It is native to the fresh waters of the North Sea and Baltic Sea basins across the northern part of France and Germany to the Alps and throughout the Danube basin, then eastwards to Siberia (Wheeler 2000).*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	7

- *This fish is found often in smaller lakes or ponds (Wheeler 2000), which differ from the Great Lakes. Otherwise, this species tolerates a wide variety of abiotic conditions, and the Great Lakes are within this range of conditions.*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0
Unknown	U
	8

- C. carassius *uses aquatic weeds for spawning (egg attachment) (FAO 2013a).*
- *This species is an open substrate spawner with eggs that adhere to twigs and macrophytes (Holopainen et al. 1997).*
- *This species does not have any habitat restrictions for normal adult life.*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9

Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0
Unknown	U
	8

- C. carassius *is very adaptable, and has already been shown to tolerate temperatures of up to 38°C (Horoszewicz 1973).*

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
	9

- C. carassius *is an omnivore that naturally feeds on organic detritus, filamentous algae, small benthic animals, and pieces and seeds of aquatic weeds. The fry/larvae feed on zooplankton (FAO 2013a).*

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in	-80% total

the Great Lakes and is not likely to be introduced	points (at end)
Unknown	U
	9

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes)	6
Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0
Unknown	U
	0

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0
Unknown	U
	-10%

- C. carassius *is vulnerable to predation, however, it has morphological adaptations (rapid growth to larger size) to avoid predation in waters with piscivores (Holopainen et al. 1997).*

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9
Frequent, moderate inocula	6
Frequent, small inocula OR infrequent, large inocula	3
Infrequent, small or moderate inocula	0
Unknown	U
	0

- *The main vector (aquarium release) is likely to be infrequent as* C. carassius *is not as common as the congeneric Goldfish (*Carassius auratus*).*

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
	3

- C. carassius *is native to local areas of England, but has been introduced in other areas of England (Wheeler 2000).*

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0

Unknown	U
	6

- C. carassius *spread occurs primarily through human release, which has been rapid due to confusing/mistaken taxonomic identification, as well as its accidental occurrence as a pet in Europe (due to misidentification with* Carassius auratus*) (Wheeler 2000).*

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing the establishment and spread of this species)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent the establishment and/or spread of this species	0
Unknown	U
	0

Establishment Potential Scorecard				
Points	**Probability for Establishment**	A. Total Points (pre-adjustment)		89
>100	High	**Adjustments**		
		B. Critical species	A*(1- 0%)	89
51-99	Moderate	C. Natural enemy	B*(1- 10%)	80.1
		Control measures	C*(1- 0%)	80.1
0-50	Low	**Potential for Establishment**		Moderate
# of questions answered as "unable to determine"	**Confidence Level**			
0-1	High	Total # of questions unknown		0
2-5	Moderate			
6-9	Low	Confidence Level		High
>9	Very low			

Section C: Potential for Impact

IMPACT POTENTIAL RESULTS

Environmental: Unknown

Socio-Economic: Low

Beneficial: Moderate

Current research on the potential for environmental impacts to result from *Carassius carassius* if introduced to the Great Lakes is inadequate to support proper assessment.

While there is some evidence that *C. carassius* may have a negative environmental impact through food competition and disturbance of surface sediment, there is uncertainty as to the magnitude of these impacts and whether they will occur in the Great Lakes.

There is little or no evidence to support that *Carassius carassius* has the potential for significant socio-economic impacts if introduced to the Great Lakes.

***Carassius carassius* has the potential for moderate beneficial impact if introduced to the Great Lakes.**

Moderate beneficial impact may occur through its value as a bait fish or though its culture for animal protein.

POTENTIAL ENVIRONMENTAL IMPACT

NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1
Not significantly	0 √
Unknown	U

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted	6

threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1
Not significantly	0
Unknown	U √

- C. carassius *is likely to be a superior competitor for food when resources are limited (Fraser and Adams 1997).*
- *Smaller eutrophic lakes or nutrient-rich, vegetated bays may have considerable numbers of carp (Hamrin 1979), though this speicies does best in monospecific ponds (Holopainen et al. 1997).*

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in the food web)	6
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	1
Not significantly	0
Unknown	U √

- C. carassius *may be a food source for piscivores such as pike, leading to hyperpredation (Fraser and Adams 1997).*

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0 √
Unknown	U

- C. carassius *hybridizes with a non-native species,* Cyprinus carpio *(Schofield et al. 2015). These hybrids have rapid growth, high resistance to polluted hypoxic water and high production of fry with excellent survival qualities (Skora and Erdmanski 1985). Others report these hybrids have low fertility (Hänfling et al. 2005).*
- C. carassius *also hybridizes with non-native species* C. gibelio *and* C. auratus *(Lusk et al. 2010).*

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR	6

Yes, and it has resulted in significant negative consequences for at least one native species	
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1
Not significantly	0
Unknown	U √

- *Benthic feeding and disturbance of surface sediment may have an important effect on nutrient cycling and trophic dynamics (Holopainen et al. 1997).*

E6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1
Not significantly	0
Unknown	U √

- C. carassius *disturbs surface sediment (Holopainen et al. 1992).*

Environmental Impact Total	**0**
Total Unknowns (U)	**4**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	Low
1	0	Low
0	≥2	**Unknown**
1	≥1	**Unknown**

POTENTIAL SOCIO-ECONOMIC IMPACT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1
Not significantly	0 √
Unknown	U

S2) Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1
Not significantly	0 √
Unknown	U

S3) Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0 √
Unknown	U

S4) Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

Socio-Economic Impact Total	**0**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**Low**
1	0	
0	≥2	Unknown
1	≥1	

POTENTIAL BENEFICIAL EFFECT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular effect. An "Unknown" response is appropriate if the potential for a particular effect might be inferred but has not been explicitly reported or if there is an unresolved debate about a particular effect.

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1
Not significantly	0 √
Unknown	U

B2) Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?

Yes, it is economically important to at least one of these industries	6

Yes, but its economic contribution is small	1 √
Not significantly	0
Unknown	U

- C. carassius *is a superb bait fish, but has low value as food in Europe (Holopainen et al. 1997).*
- *Very high growth rate in eutrophic waters makes* C. carassius *a potential producer of high quality animal protein for fodder or human food by aquaculture (Holopainen et al. 1997).*

B3) Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local communities and/or tourism	6
It is sometimes employed recreationally, but adds little value to local communities or tourism	1 √
Not significantly	0
Unknown	U

- *This species makes a superb bait fish (Holopainen et al. 1997).*

B4) Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR It is potentially important to medicine or research and is currently being or scheduled to be studied	1
Not significantly	0
Unknown	U √

- *A great potential for laboratory culture and wide range of feeding habits make Crucian Carp a suitable fish for species for routine ecotoxicologial assays (Holopainen et al. 1997).*

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1
Not significantly	0 √
Unknown	U

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1

Not significantly	0 √
Unknown	U

Beneficial Effect Total	**2**
Total Unknowns (U)	**1**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	**<u>Moderate</u>**
0	0-1	Low
1	0	
0	≥2	Unknown
1	≥1	

Scientific Name: *Channa argus*
Cantor, 1842

Common Name: Northern Snakehead

Synonyms: Amur Snakehead, Eastern Snakehead, Ocellated Snakehead, Snakehead, *Ophicephalus argus* Cantor, 1842, *Ophicephalus pekinensis* Basilewsky, 1855

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: Low

Hitchhiking/fouling: Low

Unauthorized intentional release: Moderate

Stocking/planting/escape from recreational culture: Unknown

Escape from commercial culture: Low

Transoceanic shipping: Low

***Channa argus* has a moderate probability of introduction to the Great Lakes (Confidence level: Moderate).**

Potential pathway of introduction: Dispersal, Unauthorized Intentional Release

According to the Northern Snakehead Working Group (NSWG) of the United States Fish and Wildlife Service, Channa argus (Northern Snakehead) likely arrived in United States waters by importation for the live food fish market (NSWG 2014). Unauthorized intentional release from this trade, as was the case in the founding individuals of the Crofton pond population in Maryland, continues to be the major mechanism for introduction (Courtenay and Williams 2004). The Northern Snakehead has become widely popular in ethnic markets and restaurants over the last two decades, such that this species comprised the greatest volume and weight of all live Snakehead species imported into the United States until 2001 (Courtenay and Williams 2004, NSWG 2014). In Canada, Herborg et al. (2007) identified two watersheds in the Toronto area along Lake Ontario to be at the greatest risk for northern snakehead introduction from the live fish trade; the Rideau River watershed and Cedar Creek watershed (between Lake Erie and Lake St. Clair) posed additional vectors for introduction. Snakeheads' resilient nature reportedly makes them more desirable than carps for ceremonial release, and some interest in recreational fishing may also exist (Mendoza-Alfaro et al. 2009, NSWG 2014).

Recognized as a highly injurious species, importation and cross-border transport of Northern Snakehead was prohibited in the United States by a 2002 listing under the Lacey Act and has been subsequently banned in Ontario. Nevertheless, cases of Northern Snakehead for sale in areas where possession is illegal are not uncommon (NSWG 2014). Accidental release during transport of live fish is possible, but its probability is unknown (Mendoza-Alfaro et al. 2009).

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100 √
No, this species does not occur near waters connected to the Great Lakes basin and/or is not mobile or able to be transported by wind or water.	0
Unknown	U

- *In 2004, a single specimen of Northern Snakehead was collected in Burnham Harbor, IL on Lake Michigan (NSWG 2014); no subsequent reports have been made and this introduction is considered to have failed.*
- *Although the Northern Snakehead can survive up to four days out of the water, overland migration is only possible for juveniles (Courtenay and Williams 2004).*
- *The closest established Northern Snakehead populations with respect to the Great Lakes are in Piney Creek, a tributary of the Arkansas River, AR, within the Mississippi River basin; the Potomac River basin, MD and VA; the Delaware River basin, PA and NJ; and on Long Island, NY, near the source of Flushing Creek (USGS 2012).*

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25 √
Unknown	U

- *Piney Creek is a tributary of the Arkansas River, which flows into the Mississippi River more than 100 km from the Great Lakes.*

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0 √
Unknown	U

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a) Is this species sold at aquarium/pet/garden stores ("brick & mortar" or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100 √
No, this species this species is rarely/never sold.	0
Unknown	U

- *Before importation and cross-border transport of Snakehead was prohibited by the Lacey Act in 2002 (also banned in Ontario), this fish had been available for sale in New York, Missouri, Georgia, California, Massachusetts, and Ontario.*
- *In Canada, Herborg et al. (2007) identified two watersheds in the Toronto area along Lake Ontario to be at the greatest risk for northern snakehead introduction from the live fish trade; the Rideau River watershed and Cedar Creek watershed (between Lake Erie and Lake St. Clair) posed additional vectors for introduction.*
- *Quickly attaining large size and lacking the colors of other snakehead species, northern snakehead is not a desirable aquarium fish (Courtenay and Williams 2004).*

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5√
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1
Unknown	U

- *Northern Snakehead has been widely cultured in Asian countries, particularly China, and its popularity as a food fish in American and Canadian ethnic markets has risen in the last decades. Snakeheads' resilient nature reportedly also makes them more desirable than carps for ceremonial release (Mendoza-Alfaro et al. 2009).*
- *Recognized as a highly injurious species, importation and cross-border transport of Northern Snakehead was prohibited in the United States by a 2002 listing under the Lacey Act; possession of live Snakehead is banned in 42 United States states and the Canadian province of Ontario (includes all Great Lakes states and provinces except Quebec; Courtenay and Williams 2004, IISG 2011, GLPANS 2012). Nevertheless, cases of Northern Snakehead for sale in areas where possession is illegal are not uncommon (NSWG 2014).*

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0
Unknown	U √

- *Law enforcement officials and natural resource managers in the Potomac River have observed a growing interest in fishing for Snakehead by the local population (NSWG 2014).*

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is <u>likely</u> to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces), this activity <u>may</u> occur within 20 km of the basin because of the species' popularity/value.	Score x 0.25 √
Unknown	U

<u>POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE</u>

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100
No, this species is not commercially cultured in or transported through the Great Lakes region.	0 √
Unknown	U

- *Although cross-border transport is prohibited, accidental release during illegal transport of live fish is possible; the probability of this pathway into the Great Lakes is unknown (Mendoza-Alfaro et al. 2009).*

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live	Score x 0.25

organisms within 20 km of the Great Lakes basin.	
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40
No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0 √
Unknown	U

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5
Yes, but this species has neither been observed in ballast/fouling ships entering the Great Lakes nor in ports in direct trade with the Great Lakes.	Score x 0.1
No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0
Unknown	U

Vector Potential Scorecard					
Vector		**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind		**100**	x 0.25	**25**	Low
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.		**0**	x	**0**	Unlikely
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)		**100**	x 0.5	**50**	Moderate
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)		**U**	x 0.25	**U**	Unknown
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)		**0**	x	**0**	Unlikely
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling		**0**	x	**0**	Unlikely
Total Unknowns (U)	**1**	**Confidence Level**		Moderate	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

<u>ESTABLISHMENT POTENTIAL RESULTS</u>

Status: **Established in the United States, but not the Great Lakes**

***Channa argus* has a moderate probability for establishment if introduced to the Great Lakes (Confidence level: Moderate)**

Channa argus is established in Arkansas, Maryland, New York, Pennsylvania, and Virginia, but is not established in California, Illinois, Florida, Massachusetts, or North Carolina, where only a few individual fish have been collected. In March 2009, eradication of the population in Little Piney Creek, Arkansas drainage was attempted through the application rotenone to more 700 km of creeks, ditches, and backwaters (Holt and Farwick 2009); however specimens were collected in Piney Creek later that year, indicating eradication had not been complete (L. Holt, pers. comm.). The Northern Snakehead was eradicated from the Crofton pond in Maryland where it was first established, but this species is well established in the Potomac River and several of its tributaries in Virginia and Maryland. The population in Catlin Creek, New York was also treated with rotenone. Although young fish were found, the status of the Philadelphia population is uncertain. Officials believe fish may have gotten into the lower Schuylkill River and Delaware River in Pennsylvania and see no practical means to eradicate them.

The Northern Snakehead's broad physiological tolerances, capacity to overwinter—including survival under ice, varied and flexible diet throughout at all life history stages, predatory and competitive nature, high fecundity, and parental investment in offspring, give this species a suite of favorable attributes for establishment once introduced. Northern Snakehead can adapt to a wide range of aquatic habitats and has been predicted to have high environmental suitability in the northern United States and southern Canada, including abundant potential habitat in the Great Lakes (Herborg et al. 2007, Mendoza-Alfaro et al. 2009, NSWG 2014).

Historical imports to the United States have come from a wide range of source populations, including Nigeria, Thailand, Indonesia, China, and Korea (NSWG 2014). Orrell and Weigt (2005) found seven unique mitochondrial DNA haplotypes, none of which were shared, among the five United States populations they surveyed, indicating separate introduction events and source populations for each. Such high genetic diversity among introduced populations can promote their establishment and spread (Lee 2002, Sanders 2010).

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
	9

- *Northern Snakehead has broad physiological tolerances. While it prefers maximum air temperatures of 5-16°C (Herborg et al. 2007), this species has a wider latitudinal range and temperature tolerance (0 to >30°C, including frost days) than other Snakehead species (Dukravets and Machulin 1978, Okada 1960). Upper salinity tolerances have been experimentally determined to be between 15 and 18 ppt (at temperatures of 15-*

24°C; NSWG 2014). This species is an obligate air-breather, so it is able to survive in poorly oxygenated waters.

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9
Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
	9

- *The metabolism and oxygen demand of the Northern Snakehead is reduced at low temperatures, allowing it to survive extended periods of ice cover (Frank 1970).*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
	9

- *Post-larvae Northern Snakehead feed on plankton; juveniles on small crustaceans and fish larvae; and, adults on fishes, frogs, crustaceans, and aquatic insects (Courtenay and Williams 2004).*

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	0

Unknown	U
	9

- *The voracious predatory nature of Northern Snakehead is an indication of superior competitive abilities. Its introduction into the Great Lakes would likely affect other populations of fish and invertebrates through direct predation, competition for food resources, and alteration of food webs (Courtenay and Williams 2004, NSWG 2014).*

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
	6

- *Although fecundity for this species is very high, there are variations among individuals from different regions. Northern Snakehead fecundity can range from 22,000-51,000 in its native range (Amur basin; Nikol'skii 1956) to 28,600-115,000 in an introduced population (Syr Dar'ya basin, Turkmenistan/Uzbekistan; Dukravets and Machulin 1978).*

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
	6

- *Northern Snakehead has demonstrated plasticity in timing of reproduction and rapid larval growth rates. These characteristics are likely to contribute to this species' success in new environments and limit significant invasion control (Landis et al. 2011). Additionally, both parents guard their nests from predation and continue to guard the hatched fry for several additional weeks (Courtenay and Williams 2004, Landis and Lapointe 2010).*

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- *This species can adapt to a wide range of aquatic habitats and has been predicted to have high environmental suitability in the northern USA and southern Canada (Herborg et al. 2007, Mendoza-Alfaro et al. 2009, NSWG 2014).*

8) How similar are other abiotic factors (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) that are relevant to the establishment success of this species in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	U

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0
Unknown	U
	9

- *Although this species prefers to live in stagnant shallow (< 2 m) ponds or swamps with mud substrate or aquatic vegetation and slow muddy streams, it also occurs in canals, reservoirs, lakes, and rivers (Courtenay* *and Williams 2004). Adult females build circular floating nests from clipped aquatic plants and release their pelagic, nonadhesive, buoyant eggs on top (Landis and Lapointe 2010).*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0
Unknown	U
	9

- C. argus *can adapt to a wide range of aquatic habitats and tolerate temperatures up to 30°C (Courtenay and Williams 2004).*

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
	9

- C. argus *fry initially feed on zooplankton, before moving on to a diet of small insects and crustaceans (e.g., cladocerans, copepods, small chironimid larvae). Juveniles may feed on small fish, including Goldfish (*Carassius *spp.) and Roach (*Rutilis *spp.; Courtenay and Williams 2004). As an adult, the Northern Snakehead is a voracious feeder (Okada 1960), and its diet may include fish up to 33 percent of its body length (Courtenay and Williams 2004). Adult prey items include Loach (*Cobitis *spp.), Bream (*Abramis *spp.), Carp (*Cyprinus carpio*), Perch (*Perca fluviatilis*), Zander (*Sander *spp.), Grass Carp (*Ctenopharyngodon idella*), various catfishes, crayfish, dragonfly larvae, beetles, and frogs (Courtenay and Williams 2004, Okada 1960).*

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Great Lakes and is not likely to be introduced	-80% total points (at end)
Unknown	U
	0

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes)	6
Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0
Unknown	U
	0

- *The success of young juvenile Northern Snakeheads in the Potomac River has been attributed to shelter and feeding among dense aggregations of the nonindigenous plant* Hydrilla verticillata *(Landis and Lapointe 2010).*

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0
Unknown	U
	0

- *Although all juvenile fish are susceptible to predation by larger fish, the Northern Snakehead does not have any preferential predators in the Great Lakes.*

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9
Frequent, moderate inocula	6
Frequent, small inocula OR infrequent, large inocula	3
Infrequent, small or moderate inocula	0
Unknown	U
	U

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close	3

proximity to each other)	
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
	9

- Channa argus *has been introduced and established in western Asia and eastern Europe. In the United States, there are reproducing populations in Arkansas and the Potomac River, VA (Courtenay and Williams 2004, NSWG 2014).*

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
	4

- *Although the Northern Snakehead can survive up to four days out of the water, overland migration is only possible for juveniles (Courtenay and Williams 2004). The rounded body of the adult Northern Snakehead is not as conducive to overland migration as observed in other, more horizontally flattened Snakehead species.*

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing the establishment and spread of this species)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent the establishment and/or spread of this species	0
Unknown	U
	0

Establishment Potential Scorecard

Points	**Probability for Establishment**	A. Total Points (pre-adjustment)		96
>100	High	**Adjustments**		
		B. Critical species	A*(1- 0%)	96
51-99	Moderate	C. Natural enemy	B*(1- 0%)	96
		Control measures	C*(1- 0%)	96
0-50	Low	**Potential for Establishment**		Moderate
# of questions answered as "unable to determine"	**Confidence Level**			
0-1	High	Total # of questions unknown		2
2-5	Moderate			
6-9	Low	Confidence Level		Moderate
>9	Very low			

Section C: Potential for Impact

<u>IMPACT POTENTIAL RESULTS</u>

Environmental: Unknown

Socio-Economic: Moderate

Beneficial: Moderate

Current research on the potential for environmental impacts to result from *Channa argus* if introduced to the Great Lakes is inadequate to support proper assessment.

Despite its high potential for outcompeting native species for food resources and altering food-web dynamics (Courtenay and Williams 2004, NSWG 2014) due to its voracious predatory nature, wide environmental tolerance, and varied diet, there is little published on the ecological effects of introduced northern snakehead. However, it has been predicted that Northern Snakehead could substantially modify the ecosystem balance of waters with low diversity and low abundance of native predatory species through top-down mechanisms (Courtenay and Williams 2004, Landis et al. 2011, NSWG 2014).

Among the eight forage fishes consumed by Northern Snakehead in the Potomac River, Banded Killifish (*Fundulus diaphanus*), Bluegill (*Lepomis macrochirus*), Pumpkinseed (*L. gibbosus*), and White Perch (*Morone americana*) were most commonly observed (NSWG 2014). Petr and Mitrofanov (1998) noted that an immigration of fish species to Turkmenistan from Uzbekistan, which included *C. argus warpachowskii*, caused an observed decline in the number of native species. Furthermore, Northern Snakehead could highly risk threatened and endangered species. Of all the taxa listed as endangered or threatened in United States aquatic habitats, 16 amphibians, 115 fishes, and 5 of the 21 crustaceans (surface dwelling crayfish and shrimp), would be the most likely to be affected (Courtenay and Williams 2004).

Northern Snakehead, like many other fishes, is a carrier of non-native parasites and other pathogens (including myxosporidians, cestodes, trematodes, nematodes, acanthocephalans, and copepods; Bykhovskaya-Pavlovskaya et al. 1964), which could potentially have a significant environmental impact on Great Lakes fauna. Working with researchers in Japan, the United States Fish and Wildlife Service (USFWS) identified nematodes observed in Northern Snakehead captured from the Potomac River as eustrongylides, native to United States waters; these are typically carried by the killifish the Snakehead feeds on (NSWF 2006). Additionally, Chiba et al. (1989) noted that *C. argus* (along with *C. maculata*) introduced parasites to Japan, but failed to provide details of the parasites involved or fish species affected.

Channa argus **has the potential for moderate socio-economic impact if introduced to the Great Lakes.**

In the Potomac River, the habitat and feeding preferences of northern snakehead appear to overlap with that of the recreationally important largemouth bass (*Micropterus salmoides*). Northern Snakehead has been observed to consume killifish, an important prey for white and yellow perch, as well as white perch itself (Odenkirk and Owens 2005), posing a potential impact on commercial and recreational fisheries.

Although there is little information on parasitic or disease transmission in the scientific literature available, it is known that a related species, *C. striata*, has been identified as an intermediate host for the helminth parasite that causes gnathostomiasis, a disease that can affect humans. It is still unknown if other Snakehead species may serve as an intermediate host for larvae of this parasite (Courtenay and Williams 2004).

The cost of control or eradication, should northern snakehead be introduced to the Great Lakes, could be high. Estimated costs associated with the Crofton, MD eradication effort (limited to a small pond) were over $100,000, and may be financially impossible for larger water bodies (Courtenay and Williams 2004).

Channa argus **has the potential for moderate beneficial effects if introduced the Great Lakes.**

Northern Snakehead possesses commercial importance in both native and introduced ranges. It is not only the most important snakehead cultured in China (with most culture activities centered in the Yangtze basin), but it also became commercially valuable in the deltaic area of Syrdarya after its introduction and subsequent naturalization (Aladin et al. 2008, Courtenay and Williams 2004). In addition, this species has historically been imported for sale in live-food fish markets, was previously cultured in Arkansas, and has been the most widely available snakehead in the United States (Courtenay and Williams 2004).

Channa argus is frequently in recreational and cultural activities of some communities. After becoming established in the Potomac River, natural resource managers and law enforcement officials noted and became concerned with the growing interest in fishing for Snakehead by the local population (NSWG 2014). In addition, some cultures utilize this species during prayer release (freeing captive animals into the wild as a ceremonial petition) (NSWG 2014).

Though not contributing uniquely significant research value, Chen et al. (2009) purified and characterized pepsinogens and pepsins from northern snakehead In order to investigate the digestive capacity of top-level predators.

POTENTIAL ENVIRONMENTAL IMPACT

NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1
Not significantly	0
Unknown	U √

- *Northern Snakehead, like many other fishes, is a carrier of non-native parasites and other pathogens (including myxosporidians, cestodes, trematodes, nematodes, acanthocephalans, and copepods; Bykhovskaya-Pavlovskaya et al. 1964), which could potentially have a significant environmental impact on Great Lakes fauna.*
- *Working with researchers in Japan, the United States Fish and Wildlife Service (USFWS) identified nematodes observed in Northern Snakehead captured from the Potomac River as eustrongylides, native to United States waters; these are typically carried by the killifish the Snakehead feeds on (NSWG 2014).*
- *Additionally, Chiba et al. (1989) noted that* C. argus *(along with* C. maculata*) introduced parasites to Japan, but failed to provide details of the parasites involved or fish species affected.*

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1 √
Not significantly	0
Unknown	U

- *Due to its voracious predatory nature, wide environmental tolerance, and varied diet,* C. argus *has a high potential of outcompeting native species for food resources and altering food-web dynamics (Courtenay and Williams 2004; NSWG 2014). Although little evidence of the ecological effects of introduced Northern Snakeheads can be found in the scientific literature, Petr and Mitrofanov (1998) noted that an immigration of fish species to Turkmenistan from Uzbekistan, which included* C. argus*, caused an observed decline in the number of native species.*
- *Competition for habitat is only likely to be significant during spawning seasons (Courtenay and Williams 2004).*

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in	6

the food web)	
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	1
Not significantly	0
Unknown	U √

- *There is little published analysis of the ecological effects of introduced Northern Snakehead. However, it has been predicted that Northern Snakehead could substantially modify the ecosystem balance of waters with low diversity and low abundance of native predatory species through top-down mechanisms (Courtenay and Williams 2004, Landis et al. 2011, NSWG 2014).*
- *Among the eight forage fishes consumed by Northern Snakehead in the Potomac River, Banded Killifish (*Fundulus diaphanus*), Bluegill (*Lepomis macrochirus*), Pumpkinseed (*L. gibbosus*), and White Perch (*Morone americana*) were most commonly observed (NSWG 2014).*
- *Furthermore, Northern Snakehead could further impact threatened and endangered species. Of all the taxa listed as endangered or threatened in United States aquatic habitats (16 amphibians, 115 fishes, and 5 of 21 crustaceans), those found in the Great Lakes would be the most likely species to be affected (Courtenay and Williams 2004).*

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0 √
Unknown	U

- *Because Snakeheads do not occur naturally in the United States, hybridizing or interbreeding with native fishes is not likely (Courtenay and Williams 2004).*

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1
Not significantly	0 √
Unknown	U

E6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1
Not significantly	0 √
Unknown	U

- *The Northern Snakehead is not likely to cause habitat degradation or destruction (Courtenay and Williams 2004).*

Environmental Impact Total	**1**
Total Unknowns (U)	**2**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	Low
1	0	
0	≥2	**Unknown**
1	≥1	

POTENTIAL SOCIO-ECONOMIC IMPACT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1
Not significantly	0
Unknown	U √

- *There is little information on parasitic or disease transmission by this species available in the scientific literature. However, it is known that a related species,* Channa striata*, has been identified as an intermediate host for the helminth parasite that causes gnathostomiasis, a disease that can affect humans. It is still unknown if other Snakehead species may serve as an intermediate host for larvae of this parasite (Courtenay and Williams 2004).*

S2) Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1
Not significantly	0 √
Unknown	U

S3) Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0 √
Unknown	U

S4) Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1 √
Not significantly	0
Unknown	U

- *In the Potomac River, northern snakehead has been observed to consume Killifish, an important prey for White and Yellow Perch, as well as White Perch itself (Odenkirk and Owens 2005), posing a potential impact on commercial and recreational fisheries.*

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6
Yes, but negative consequences have been small	1 √
Not significantly	0
Unknown	U

- *In the Potomac River, the habitat and feeding preferences of Northern Snakehead appears to overlap with that of the recreationally important Largemouth Bass (*Micropterus salmoides*). Northern Snakehead has been observed to consume Killifish, an important prey for White and Yellow perch, as well as White perch itself (Odenkirk and Owens 2005), posing a potential impact on commercial and recreational fisheries.*

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly	6

diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

Socio-Economic Impact Total	**2**
Total Unknowns (U)	**1**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	**<u>Moderate</u>**
0	0-1	Low
1	0	
0	≥2	Unknown
1	≥1	

<u>POTENTIAL BENEFICIAL EFFECT</u>

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular effect. An "Unknown" response is appropriate if the potential for a particular effect might be inferred but has not been explicitly reported or if there is an unresolved debate about a particular effect.

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1
Not significantly	0 √
Unknown	U

B2) Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?

Yes, it is economically important to at least one of these industries	6
Yes, but its economic contribution is small	1 √
Not significantly	0
Unknown	U

- *Northern Snakehead possesses commercial importance in both native and introduced ranges. It is not only the most important snakehead cultured in China (with most culture activities centered in the Yangtze basin), but it also became commercially valuable in the deltaic area of Syr Darya after its introduction and subsequent naturalization (Aladin et al. 2008, Courtenay and Williams 2004).*
- *In addition, this species has historically been imported for sale in live-food fish markets, was previously cultured in Arkansas, and has been the most widely available Snakehead in the United States (Courtenay and Williams 2004).*

B3) Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local communities and/or tourism	6
It is sometimes employed recreationally, but adds little value to local communities or tourism	1 √
Not significantly	0
Unknown	U

- Channa argus *is frequently used in recreational and cultural activities of some communities. After becoming established in the Potomac River, natural resource managers and law enforcement officials noted and became concerned with the growing interest in fishing for Snakeheads by the local population (NSWG 2014).*
- *In addition, some cultures utilize this species during prayer release (freeing captive animals into the wild as a ceremonial petition) (NSWG 2014).*

B4) Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR It is potentially important to medicine or research and is currently being or scheduled to be studied	1
Not significantly	0 √
Unknown	U

- *In order to investigate the digestive capacity of top-level predators, Chen et al. (2009) purified and characterized pepsinogens and pepsins from Northern Snakehead.*

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1
Not significantly	0 √
Unknown	U

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1
Not significantly	0 √
Unknown	U

Beneficial Effect Total	**2**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	**<u>Moderate</u>**
0	0-1	Low
1	0	
0	≥2	Unknown
1	≥1	

Scientific Name: *Clupeonella cultriventris*
Nordmann, 1840

Common Name: Black Sea Sprat, Caspian Sea Sprat, Azov Kilka, Common Kilka, Tyulka

Synonyms:

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: Unlikely

Hitchhiking/fouling: Unlikely

Unauthorized intentional release: Unlikely

Stocking/planting/escape from recreational culture: Unlikely

Escape from commercial culture: Unlikely

Transoceanic shipping: Low

***Clupeonella cultriventris* has a low probability of introduction to the Great Lakes (Confidence level: High).**

Potential pathway(s) of introduction: Transoceanic Shipping (ballast water)

Clupeonella cultriventris is native to the Ponto-Caspian region (Fazli et al. 2007). This species is not known to hitchhike or foul vessels. *Clupeonella cultriventris* is not stocked, commercially cultured, or sold in the Great Lakes region. Although this species occurs in waters from which shipping traffic to the Great Lakes originates, it does not currently occur in ports that have direct trade connections with the Great Lakes and has not been observed in ballast tanks of ships entering the Great Lakes. It may be able to survive ballast tank environment due to its high salinity tolerance (Fazli et al. 2007).

In the Rybinsk Reservoir, *Clupeonella cultriventris* has been locally introduced to the Dneiper, Volga, and Kama rivers after the construction of dams (Kiyashko et al. 2006). It has not been introduced further north towards the Volga-Baltic canal system (Kiyashko et al. 2012).

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100
No, this species does not occur near waters connected to the Great Lakes basin and/or is	0 √

not mobile or able to be transported by wind or water.	
Unknown	U

- Clupeonella cultriventris *currently inhabits the Ponto-Caspian region, including Iranian and Turkish waters of the Caspian Sea (Fazli et al. 2007).*

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0 √
Unknown	U

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a) Is this species sold at aquarium/pet/garden stores ("brick & mortar" or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100
No, this species this species is rarely/never sold.	0 √

Unknown	U

- *An Internet search for* C. cultriventris *for purchase ("for sale") suggests that this species in not sold.*

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0 √
Unknown	U

- *An Internet search provided no information that would suggest* C. cultriventris *is anywhere in the Great Lakes region.*

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is likely to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces), this activity may occur within 20 km of the basin because of the species' popularity/value.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100

No, this species is not commercially cultured in or transported through the Great Lakes region.	0 √
Unknown	U

- Clupeonella cultriventris *is not currently cultured in Great Lakes region.*

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80 √
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40
No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0
Unknown	U

- *This species is euryhaline and is found in salinities up to 36‰ (Fazli et al. 2007).*
- *This species occurs in waters with temperatures of 2.6 - 26°C, but its optimal temperature range is 16 - 22 °C (Aseinova 2003, Stakenas 2011).*

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1
Yes, and this species has been observed in ports that have direct trade connections with	Score x 0.5

the Great Lakes (e.g., Baltic Sea).	
Yes, but this species has neither been observed in ballast/fouling ships entering the Great Lakes nor in ports in direct trade with the Great Lakes.	Score x 0.1 √
No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0
Unknown	U

- Clupeonella cultriventris *has successfully established in the Rhine River due to opening of Rhine-Main-Danube canal that connects to the Black Sea (Ricciardi and MacIsaac 2000).*
- Clupeonella cultriventris *spread to the Volga reservoirs to the Rybinsk Reservoir, but was unable to move further north through the Volga-Baltic canal system (Kiyashko et al. 2012).*
- Clupeonella cultriventris *is found in the Black Sea (northwestern parts), Sea of Azov, and Caspian Sea, as well as most of the affluent rivers of the area, reaching as far as 60 km inland. It is also found in Lake Palaeostomi (Bulgaria), the Bay of Feodosiya (Romania), and Lake Apolyont (Turkey) (Whitehead 1985).*
- *As such, it does not appear that* C. cultriventris *currently exists at ports in direct trade with the Great Lakes.*

Vector Potential Scorecard					
Vector		**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind		**0**	x	**0**	Unlikely
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.		**0**	x	**0**	Unlikely
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)		**0**	x	**0**	Unlikely
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)		**0**	x	**0**	Unlikely
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)		**0**	x	**0**	Unlikely
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling		**80**	x 0.1	**8**	Low
Total Unknowns (U)	**0**	**Confidence Level**		High	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate

1-39	Low
0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

ESTABLISHMENT POTENTIAL RESULTS

Status: **Not established in North America, including the Great Lakes**

***Clupeonella cultriventris* has a moderate probability of establishment if introduced to the Great Lakes (Confidence level: High).**

The native and introduced ranges of *Clupeonella cultriventris* have similar climatic and abiotic conditions as the Great Lakes (Grigorovich et al. 2003, Reid and Orlova 2002, USEPA 2008). *Clupeonella cultriventris* can tolerate freshwaters and salinities up to 36 % (Fazli et al. 2007). It occurs in waters with temperatures of 2.6-26 °C and is oxyphilic (Aseinova 2003); thus this species is somewhat likely to be capable of overwintering in the Great Lakes, but its ability to do so is limited by the oxygen level in the water. Climate change may make the Great Lakes more suitable for *Clupeonella cultriventris*. Its optimal temperature range is 16-22°C and may benefit from warmer water temperatures. It is oxyphilic so it may benefit from shorter duration of ice cover. If introduced, it is probable that *Clupeonella cultriventris* will find an appropriate food source of copepods and cladocerans. Compared to closely related species, *Clupeonella cultriventris* has a flexible diet (Fazli et al. 2007). In its native range, *Clupeonella cultriventris* is eaten by piscivorous fish such as salmon and sturgeons (Karimzadeh 2011). Lake sturgeon and several types of salmon are present in the Great Lakes (MIDNR 2014). Lake sturgeon is a benthic feeder and occurs in the Great Lakes in low abundances (Hayes and Caroffino 2012), so it is unlikely to prey on this species. *Clupeonella cultriventris* has a shorter breeding season than Bigeye Kilka (*Clupeonella grimmi*), which reproduces year round (Karimzadeh et al. 2010). The average absolute fecundity of *Clupeonella cultriventris* 25,400 eggs (Opisov and Kiyashko 2006), which is greater than the absolute fecundity of Anchovy Kilka (*Clupeonella engrauliformis*) that is 12625 ± 5533 eggs (Janbaz et al. 2012). The fecundity of *Clupeonella cultriventris* may be greater in fresh waters such as the Great Lakes.

Clupeonella cultriventris dominated pelagic fish communities of the Volga and Sheksna reservoirs (Slynko et al. 2002) and continues to spread northwards as average water temperatures rise with the progression of climate change (Kiyashko et al. 2006). The lack of competitors and low predation pressure in these reservoirs as well as eutrophication, retarded flow, and the creation of habitats suitable for pelagic fish may have contributed to their spread and dominance in the fish communities. The dominance of this species in the reservoirs of the Volga River may have suppressed native fish populations (Mordukhaĭ-Boltovskoĭ 1979b, Ricciardi and Rasmussen 1998). In locations where *Clupeonella cultriventris* is very abundant, its diet is similar to the diets of native species, with a feeding similarity index greater than 50% (Kiyashko et al. 2007). On the other hand, where this species is less numerous, its feeding similarity with native species is less than 40%. It may compete with planktivorous fish for zooplankton.

Models predicted that *Clupeonella cultriventris* will spread at a fast rate and have negative impacts if introduced (Kolar and Lodge 2002). The spread of this species throughout the Dniester, Danube, Dnieper, Don, Kuban, Volga, and Ural rivers is thought to be facilitated by the construction of reservoirs (Kiyashko et al. 2006). *Clupeonella cultriventris* completely colonized the Uglich and Ivan'kov Rivers within a span of 12 years (Kiyashko et al. 2006).

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
	6

- Clupeonella cultriventris *is known to have broad salinity and temperature tolerance. It is considered oxyphillic (Aseinova 2003).*
- *This species is euryhaline. It can tolerate freshwaters and salinities up to 36% (Fazli et al. 2007).*
- *It is found in waters that have an annual average temperature of 12°C (Karimzadeh et al. 2010) and can tolerate water temperatures down to 3°C (Kas'yanov 2009). It occurs in waters with temperatures ranges of 2.6-26°C, and its optimal temperature is 16-22°C (Stakenas 2011). Spawning and development occurs at 10-25°C in the pelagic zone (Kiyashko et al. 2006). It is considered eurythermal (Ricciardi and Rasmussen 1998).*

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9
Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
	7

- Clupeonella cultriventris *is known to be an overwintering species, however oxygen requirements may limit overwintering (Aseinova 2003).*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
	8

- Clupeonella cultriventris *is a euryphagous species, eating wide variety of copepods, cladocerans, and rotifers (Aseinova 2003).*
- Clupeonella cultriventris *feeds during the day (Kiyashko et al. 2007).*
- *Clupeonella cultriventris feeds on zooplankton and its diet is relatively diverse relative to other kilka species (Fazli et al. 2007).*

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	0
Unknown	U
	3

- *Kolar and Lodge (2002) notes that a previous qualitative assessment suggests that Tyulka (*Clupeonella cultriventris*) may have negative effects on the Great Lakes if introduced.*
- *Kolar and Lodge (2002) predicted that* Clupeonella cultriventris *would spread quickly and be a nuisance if introduced to the Great Lakes.*
- *It dominates the pelagic planktivorous fish assemblages in almost all reservoirs of the Volga cascade, including the Rybinsk Reservoir. The northward expansion of kilka is still continuing. In 2001 it dominated fish communities from Sheksna Reservoir to Beloye Lake (Slynko et al. 2002). Eutrophication, retarded flow, and formation of vast open sites suitable for these pelagic fish contributed to their dispersal and naturalization (Kiyashko et al. 2006). In addition, the nearly complete absence of competitors and low predator pressure may have been partially responsible for their spread and their dominance in the communities.*
- *Where this species is very abundant, it feeds on the same planktonic organisms as native species, and their feeding similarity indices are greater than 50%. When this species is less numerous, feeding similarity with native species is less than 40% (Kiyashko et al. 2007).*
- *It has become very abundant in the Volga River reservoirs, contributing to the decline in native populations (Mordukhaĭ-Boltovskoĭ 1979b, Ricciardi and Rasmussen 1998).*

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
	3

- Clupeonella cultriventris *reaches maturity after one year (Kiyashko et al. 2006).*
- *Reproduction occurs from March to September at temperatures of 10-25°C (Fazli et al. 2007, Karimzadeh et al. 2010, Kiyashko et al. 2006) and peaked in April-May. It has a shorter reproduction period than the bigeye kilka (throughout the year).*
- *In the Rybinsk Reservoir, it begins spawning in early June and ends in late July, peaking in early July (Opisov and Kiyashko 2006). It reaches maturity at age one+ years at 49 mm. Males live up to 3.5 years. Females live longer. Females produce at least two batches of eggs during the spawning period. Absolute fecundity range from 4.2 to 66.7 thousand eggs and averages at 25.4 thousand eggs. Fecundity increases in freshwater.*
- *The Anchovy Kilka,* Clupeonella engrauliformis*, has an average absolute fecundity of 12625 ± 5533 eggs (Janbaz et al. 2012).*
- *It produces more eggs than anchovy kilka but spawns for a shorter time period than Bigeye Kilka. The number of eggs produced by Bigeye Kilka is unknown.*

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
	3

- *Based on egg size, amount of eggs laid per fish, and early maturity it is likely that these will all give* C. cultriventris *a reproductive advantage. (Kiyashko et al. 2006, Opisov and Kiyashko 2006).*
- *Fish that produce a large number of small eggs may be more likely to establish than other fish (Kolar and Lodge 2002).*

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- *The Ponto-Caspian (Caspian, Azov, and Black Seas) have similar climate and surface water temperature ranges as the Great Lakes (Grigorovich et al. 2003, Reid and Orlova 2002, USEPA 2008).*
- *The Great Lakes and Ponto-Caspian region are climatically compatible, which is one of the attributing factors to the success of Ponto-Caspian species in the Great Lakes (Reid and Orlova 2002).*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- *Although* C. cultriventris *is native to brackish waters of the Ponto-Caspian, it has established in freshwaters of the Rhine River (Ricciardi and MacIsaac 2000).*
- *Great Lakes underwent similar anthropogenic eutrophication as the Ponto-Caspian region (Reid and Orlova 2002). Surface water temperature is similar between the Great Lakes and Ponto-Caspian seas (Grigorovich et al. 2003, Reid and Orlova 2002, USEPA 2008).*
- *Abiotic factors and climatic conditions of the native and introduced ranges of* C. cultriventis *are quite similar to the Great Lakes, making the region compatible (Grigorovich et al. 2003, Reid and Orlova 2002).*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0

Unknown	U
	6

- Clupeonella cultriventris *is a pelagic fish that inhabits coastal areas shallower than 50-70 m (Fazli and Besharat 1998). It is oxyphillic, but can tolerate a wide range of temperatures (Aseinova 2003).*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0
Unknown	U
	5

- *Its optimal temperature range is 16 -22°C (Aseinova 2003). It may not be able to tolerate low dissolved oxygen levels (Aseinova 2003) created by ice cover, so shorter ice cover duration may benefit this species. Climate change may make the Great Lakes climate more similar to the Ponto-Caspian region (USEPA 2008).*

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
	8

- Clupeonella cultriventris *feeds on wide variety of copepods, cladocerans, and rotifers (Aseinova 2003). These can be found in the Great Lakes.*
- *Compared to closely related species,* Clupeonella cultriventris *has a flexible diet (Fazli et al. 2007).*

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Great Lakes and is not likely to be introduced	-80% total points (at end)
Unknown	U
	9

- *There is no critical species required by* C. cultriventris.

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes)	6
Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0
Unknown	U
	0

- *There are no Great Lakes species known to facilitate the establishment of* C. cultriventris.

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0
Unknown	U
	-10%

- *Major predators of adult* C. cultriventris *include larger fish (Aseinova 2003), but these are unlikely to be a significant deterrent to species establishment.*
- *In the Caspian Sea,* C. cultriventris *is an important part of the diet of commercially valuable fish such as sturgeon and salmon (Karimzadeh 2011).*
- *Lake Sturgeon is threatened (in low abundance) in the Great Lakes (Hayes and Caroffino 2012).*
- *Chinook Salmon was introduced to the Great Lakes and its populations are maintained by stocking programs (MIDNR 2014).*

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9
Frequent, moderate inocula	6
Frequent, small inocula OR infrequent, large inocula	3
Infrequent, small or moderate inocula	0
Unknown	U
	U

- Clupeonella cultriventris *has not yet been introduced into the Great Lakes and potential inoculum size and frequency are not known.*

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9

Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
	4

- *There are reported invasive* C. cultriventris *populations in Russia and Belarus (Khalko 2007, Kiyashko et al. 2006, Semenchenko 2008, Slynko et al. 2002). Its distribution is continuing to spread northwards. The spread has been primarily attributed to the construction of reservoirs.*

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
	7

- C. cultriventris *dominates the pelagic planktivorous fish assemblages in almost all reservoirs of the Volga cascade, including the Rybinsk Reservoir. The northward expansion of kilka is still continuing. In 2001 it dominated fish communities from Sheksna Reservoir to Beloye Lake (Slynko et al. 2002). Eutrophication, retarded flow, and formation of vast open sites suitable for these pelagic fish contributed to their dispersal and naturalization (Kiyashko et al. 2006). In addition, the nearly complete absence of competitors and low predator pressure may have been partially responsible for their spread and their dominance in the communities.*
- Clupeonella cultriventris *completely colonized the Uglich and Ivan'kov reservoirs of the Volga River within a span of 12 years (Kiyashko et al. 2006).*
- *The models developed by Kolar and Lodge (2002) predicted that* Clupeonella cultriventris *will spread at a fast rate and have negative impacts if introduced.*
- *It has populated the lower reaches of the Kama River in 1963-1966 (Mordukhaĭ-Boltovskoĭ 1979a).*

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing the establishment and spread of this species)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control	-20% total points (at

its establishment and spread)	end)
No control methods have been set to prevent the establishment and/or spread of this species	0
Unknown	U
	0

- *No control methods for this species are known to be present in the Great Lakes.*

Establishment Potential Scorecard				
Points	**Probability for Establishment**	A. Total Points (pre-adjustment)		85
>100	High	**Adjustments**		
		B. Critical species	A*(1- 0%)	85
51-99	Moderate	C. Natural enemy	B*(1- 10%)	76.5
		Control measures	C*(1- 0%)	76.5
0-50	Low	**Potential for Establishment**		Moderate
# of questions answered as "unable to determine"	**Confidence Level**			
0-1	High	Total # of questions unknown		1
2-5	Moderate			
6-9	Low	Confidence Level		High
>9	Very low			

Section C: Potential for Impact

IMPACT POTENTIAL RESULTS

Environmental: Unknown

Socio-Economic: Low

Beneficial: Low

Current research on the potential for environmental impacts to result from *Clupeonella cultriventris* if introduced to the Great Lakes is inadequate to support proper assessment.

There is insufficient information available to determine whether *Clupeonella cultriventris* poses a threat to water quality. It is unknown whether this species alters the physical components of the ecosystem. If introduced to the Great Lakes, *Clupeonella cultriventris* poses a threat to areas that lack important forage fish, which may contribute to the growing contaminant levels in piscivores (Ricciardi and Rasmussen

1998); however, this effect has not been specifically documented for *Clupeonella cultriventris*. It dominates pelagic fish communities in the Volga and Sheksna reservoirs (Slynko et al. 2002). The dominance of *Clupeonella cultriventris* in the Volga may have suppressed native populations (Mordukhaĭ-Boltovskoĭ 1979b, Ricciardi and Rasmussen 1998); however, there is insufficient information available to determine which species were impacted. *Clupeonella cultriventris* may compete with other planktivorous pelagic fish if it attains a large population in the Great Lakes. In locations where *Clupeonella cultriventris* is very abundant, its diet is similar to the diets of native species, with a feeding similarity index greater than 50% (Kiyashko et al. 2007). On the other hand, where this species is less numerous, its feeding similarity with native species is less than 40%.

There is little or no evidence to support that *Clupeonella cultriventris* has the potential for significant socio-economic impacts if introduced to the Great Lakes.

It has not been reported that *Clupeonella cultriventris* poses a threat to human health or water quality. There is no evidence that this species negatively impacts infrastructure, economic sectors, recreational activities and associated tourism, or the aesthetic appeal of the areas it inhabits.

There is little or no evidence to support that *Clupeonella cultriventris* has the potential for significant beneficial impacts if introduced to the Great Lakes.

This species one of the most abundant fish in the Caspian Sea and are commercially valuable in fisheries (Fazli et al. 2007). It is an important source of protein and income for people living in the Caspian Sea (Karimzadeh et al. 2010) and is preyed on by commercially valuable fish such as sturgeon and salmon (Karimzadeh 2011). It is uncertain whether *Clupeonella cultriventris* would make a significant contribution to North American fisheries. It has not been indicated that *Clupeonella cultriventris* can be used for the control of other organisms or improving water quality. There is no evidence to suggest that this species is recreationally or medically valuable. It does not have significant positive ecological impacts.

POTENTIAL ENVIRONMENTAL IMPACT

NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1
Not significantly	0
Unknown	U √

- *No reports of hazardous effects on native populations were found.*
- *If introduced Bigeye Tulka poses the added threat of invading lakes that are currently devoid of important pelagic forage fish, which could result in increased contaminant levels in piscivores, an effect already*

documented for introduced smelt (Vander Zanden and Rasmussen 1996). However, this effect has not been specifically documented for Clupeonella cultriventris *(Ricciardi and Rasmussen 1998).*

- *It dominates pelagic fish communities in the Volga and Sheksna reservoirs (Slynko et al. 2002). The dominance of* Clupeonella cultriventris *in the Volga may have suppressed native populations (Mordukhaĭ-Boltovskoĭ 1979b, Ricciardi and Rasmussen 1998); however, it is unknown what species were impacted.*

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1
Not significantly	0
Unknown	U √

- Clupeonella cultriventris *is successful at establishing in non-native regions, though no data on its effect on specific native species were found.*
- *It has extended its range towards the Volga and Sheksna reservoirs, where it dominates pelagic fish communities (Slynko et al. 2002). The lack of competitors and low predation pressure in these reservoirs, as well as eutrophication, retarded flow, and the creation of habitats suitable for pelagic fish may have contributed to their spread and dominance over fish communities (Kiyashko et al. 2006). The dominance of this species in the Volga River reservoirs may have suppressed native fish populations (Mordukhaĭ-Boltovskoĭ 1979b , Ricciardi and Rasmussen 1998). However, the identity of the species that have been impacted by* Clupeonella cultriventris *dominance remains unknown.*
- *In locations where* Clupeonella cultriventris *is very abundant, its diet is similar to the diets of native species, with a feeding similarity index greater than 50% (Kiyashko et al. 2007). On the other hand, where this species is less numerous, its feeding similarity with native species is less than 40%. Thus, it may compete with planktivorous fish for zooplankton if it attains a large population in the Great Lakes.*

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in the food web)	6
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	1
Not significantly	0
Unknown	U √

- *In its native range,* C. cultriventris *is important as predator and prey, but nothing was found pertaining to its role in invaded ecosystems.*

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0
Unknown	U √

- *A genetic effect of* C. cultriventris *on other populations is not known.*

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1
Not significantly	0
Unknown	U √

- *No reports of water quality alteration were found.*

E6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1
Not significantly	0
Unknown	U √

- *No information about additional environmental impacts was found.*

Environmental Impact Total	**0**
Total Unknowns (U)	**6**

Scoring		
Score	# U	Impact
>5	Any	High

<table>
<tr><td>2-5</td><td>Any</td><td>Moderate</td></tr>
<tr><td>0</td><td>0-1</td><td rowspan="2">Low</td></tr>
<tr><td>1</td><td>0</td></tr>
<tr><td>0</td><td>≥2</td><td rowspan="2"><u>Unknown</u></td></tr>
<tr><td>1</td><td>≥1</td></tr>
</table>

POTENTIAL SOCIO-ECONOMIC IMPACT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1
Not significantly	0 √
Unknown	U

- Clupeonella cultriventris *can be consumed by humans, and there are no reports of threat to human health.*

S2) Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1
Not significantly	0 √
Unknown	U

- *There are no reports of this species causing damage to infrastructure.*

S3) Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0 √
Unknown	U

- *There are no reports of this species altering water quality.*

S4) Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

- *There are no reports of this species affecting markets or other economic sectors.*

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

- *There are no reports of this species inhibiting recreational activities.*

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

- *There are no reports of this species diminishing aesthetic values.*

Socio-Economic Impact Total	**0**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**Low**
1	0	
0	≥2	Unknown
1	≥1	

POTENTIAL BENEFICIAL EFFECT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular effect. An "Unknown" response is appropriate if the potential for a particular effect might be inferred but has not been explicitly reported or if there is an unresolved debate about a particular effect.

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1
Not significantly	0 √
Unknown	U

- *There are no reports of this species acting as a biological control.*

B2) Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?

Yes, it is economically important to at least one of these industries	6
Yes, but its economic contribution is small	1 √
Not significantly	0
Unknown	U

- *There are suggestions for its potential use in Russian commercial fisheries (Aseinova 2003).*
- *In the Caspian,* Clupeonella cultriventris *is an important source of income and protein for many people in the region (Karimzadeh et al. 2010) and is preyed on by commercially valuable fish such as sturgeon and salmon (Karimzadeh 2011). Whether this species will make a significant contribution to North American fisheries is uncertain.*

B3) Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local communities and/or tourism	6
It is sometimes employed recreationally, but adds little value to local communities or tourism	1
Not significantly	0 √
Unknown	U

- *There are no suggestions of this species having recreational value.*

B4) Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR	1

It is potentially important to medicine or research and is currently being or scheduled to be studied	
Not significantly	0 √
Unknown	U

- *There is no information about a potential medicinal or research value of this species.*

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1
Not significantly	0 √
Unknown	U

- *No reports of water quality improvement by this species were found.*

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1
Not significantly	0 √
Unknown	U

- *Sturgeon preys on* Clupeonella cultriventris *(Karimzadeh 2011). Lake Sturgeon occurs in the Great Lakes and is listed as threatened in Michigan (MIDNR 2009). However, increasing the amount of food available for lake sturgeon may not contribute to their conservation; they are threatened due to overfishing and declining habitat quality rather than the lack of food. In addition, the Lake Sturgeon is a benthic feeder (Hayes and Caroffino 2012), so there is a possibility that it will not feed on the pelagic* Clupeonella cultriventris.

Beneficial Effect Total	**1**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**Low**
1	0	

0	≥2	Unknown
1	≥1	

Scientific Name: *Cottus gobio*
Linnaeus, 1758

Common Name: Bullhead

Synonyms:

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: Unlikely

Hitchhiking/fouling: Unlikely

Unauthorized intentional release: Unlikely

Stocking/planting/escape from recreational culture: Unlikely

Escape from commercial culture: Unlikely

Transoceanic shipping: Moderate

***Cottus gobio* has a moderate probability of introduction to the Great Lakes (Confidence level: High).**

Potential pathway(s) of introduction: Transoceanic Shipping (ballast water)

Cottus gobio does not occur near waters connected to the Great Lakes. It is not known to hitchhike or foul. *Cottus gobio* is not stocked, commercially cultured, or sold in the Great Lakes region. This species occurs in ports that have direct trade connections with the Great Lakes (NBIC 2009). *Cottus gobio* may survive ballast tank environments; however, ballast water exchange regulations that require flushing with full-strength seawater are likely to prevent its introduction due to its salinity tolerance. *Cottus gobio* may be introduced to the Great Lakes via ships declaring "No Ballast on Board" (NOBOB), which are exempt from ballast water exchange. The majority of ships entering the Great Lakes are NOBOB vessels and 43% of these ships contain residual water with less than 10% salinity (Johengen et al. 2005). In the study, the temperature of the residual water from the vessels sampled ranged from -0.7 to 23.9°C; thus *Cottus gobio* is likely to survive the salinity and temperature of the NOBOB ballast water.

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100

No, this species does not occur near waters connected to the Great Lakes basin and/or is not mobile or able to be transported by wind or water.	0 √
Unknown	U

- *Analysis of genetic structure shows* Cottus gobio *was first found in Northwestern Europe and then in the British freshwater system (Dorts et al. 2012).*

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0 √
Unknown	U

- Cottus gobio *lives in the benthic zone but it is unlikely to attach to particular surfaces.*

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a) Is this species sold at aquarium/pet/garden stores ("brick & mortar" or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100

No, this species this species is rarely/never sold.	0 √
Unknown	U

- Cottus gobio *is not available for purchase in North America, though it is used as bait in Europe.*

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0 √
Unknown	U

- Cottus gobio *is not known to be stocked in the Great Lakes region.*

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is likely to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces), this activity may occur within 20 km of the basin because of the species' popularity/value.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100

No, this species is not commercially cultured in or transported through the Great Lakes region.	0 √
Unknown	U

- *There is no evidence of this species being commercially cultured or transported though the Great Lakes.*

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80 √
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40
No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0
Unknown	U

- Cottus gobio *is predicted to be able to invade the Great Lakes in ballast water (Kolar and Lodge 2002).* Cottus gobio *may survive ballast tank environments; however, ballast water exchange regulations that require flushing with full-strength seawater are likely to prevent its introduction due to its salinity tolerance.*

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5 √

Yes, but this species has neither been observed in ballast/fouling ships entering the Great Lakes nor in ports in direct trade with the Great Lakes.	Score x 0.1
No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0
Unknown	U

- Cottus gobio *is widely distributed throughout Europe, from Greenland and Scandinavia to Italy, including England and Wales (Tomlinson and Perrow 2003).*

Vector Potential Scorecard					
Vector		**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind		**0**	x	**0**	Unlikely
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.		**0**	x	**0**	Unlikely
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)		**0**	x	**0**	Unlikely
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)		**0**	x	**0**	Unlikely
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)		**0**	x	**0**	Unlikely
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling		**80**	x 0.5	**40**	Moderate
Total Unknowns (U)	0	**Confidence Level**		High	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

ESTABLISHMENT POTENTIAL RESULTS

Status: **Not established in North America, including the Great Lakes**

***Cottus gobio* has a moderate probability of establishment if introduced to the Great Lakes (Confidence level: Moderate).**

The native and introduced ranges of *Cottus gobio* have similar climatic and abiotic conditions as the Great Lakes (Grigorovich et al. 2003, Reid and Orlova 2002, USEPA 2008). This species can tolerate the temperature of the Great Lakes during the winter, but as an oxyphilic species, may not be capable of overwintering in waters with low-oxygen levels. Evidence suggests that increased water temperatures due to climate change may negatively impact reproductive physiology of *Cottus gobio*. Gonadal maturation for male and female fish was disrupted when water temperature was raised 8°C, reflecting complete reproductive failure (Dorts et al. 2012). This fish commonly inhabits cold, well-oxygenated streams and lakes, but has been found in large stagnant water bodies as a nonindigenous species (Nolte et al. 2005). Appropriate habitats are somewhat available in the Great Lakes. Hybrids of 2 *Cottus gobio* populations are thought to have greater potential to adapt to new habitats. The diet of *Cottus gobio* is flexible, and changes seasonally. The prey types in its diet are present in the Great Lakes.

There is no indication that *Cottus gobio* is a strong competitor. In the River Great Ouse, Britain, a crayfish native to North America, *Pacifastacus leniusculus* (Dana), competes with *Cottus gobio* for shelter, and reduces its abundance (Guan and Wiles 1997). *Pacifastacus leniusculus* does not currently occur in the Great Lakes. *Cottus gobio* may be preyed on by some fish that occur in the Great Lakes including *Salmo trutta* and *Esox lucius* (Fuller et al. 2014, Fuller 2013).

Cottus gobio has moderate fecundity (Hänfling and Weetman 2006, Vila-Gispert et al. 2005). It requires large stones to make nests in order to reproduce (Smyly 1957); it is unlikely that the reproductive strategy of this species will aid its establishment in the Great Lakes.

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
	7

- Cottus gobio *predominantly occurs in stony streams and rivers where the flow is moderate and the water is cool and oxygen rich (Tomlinson and Perrow 2003).*
- Cottus gobio *found in critical thermal limits temperature of -4.2 and 27.7˚C (Tomlinson and Perrow 2003).*

- Cottus gobio *inhabits lakes and rivers (Smyly 1957).*
- *This species occurs in brackish waters such as the Baltic Sea, which has salinities < 7 ppt (Kontula and Väinölä 2001).*
- *The density of* Cottus gobio *is negatively correlated to DOC concentration and is absent in waters above 3 mg C L^{-1} (Utzinger et al. 1998).*

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9
Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
	7

- Cottus gobio *is found in critical thermal limits temperature of -4.2 and 27.7°C (Tomlinson and Perrow 2003).*
- *It commonly inhabits well-oxygenated waters, but has been found in large stagnant water bodies as nonindigenous species (Nolte et al. 2005). It may be able to tolerate the low temperatures as low as -4.2°C over the winter, but it is not known whether it can tolerate low oxygen levels in the Great Lakes.*
- *Due to the climatic similarities between the Great Lakes and Ponto-Caspian regions (Reid and Orlova 2002)* Cottus gobio *most likely endures similar overwintering conditions in its native range.*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
	7

- *Its diet changes with seasons; generally crustaceans are taken in the winter and a wide range of insect larvae in the summer (Tomlinson and Perrow 2003).*
- Cottus gobio *feeds on benthic invertebrates (Smyly 1957). In the winter,* Gammarus *amphipods were a large component of their diet (Mills and Mann 1983), and in the summer, these fish hit their peak consumption of Plecoptera nymphs.These prey items occur in the Great Lakes.*

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9

Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	0
Unknown	U
	0

- Cottus gobio *is a poor competitor and can be outcompeted by large fish (Tomlinson and Perrow 2003).*
- *In the River Great Ouse in Britain, a North American crayfish* Pacifastacus leniusculus *competes with* Cottus gobio *for shelter and reduces its abundance (Guan and Wiles 1997).* Pacifastacus leniusculus *does not currently occur in the Great Lakes.*

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
	6

- Cottus gobio *grows rapidly, matures early but is short-lived in lowland streams, with only three age classes represented in the population (Tomlinson and Perrow 2003).*
- Cottus gobio *has moderate fecundity according to Hänfling and Weetman (2006) and Vila-Gispert et al. (2005).*

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0

Unknown	U
	0

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	7

- Cottus gobio *has been established in United Kingdom rivers, which are similar to Great Lakes environment (Tomlinson and Perrow 2003).*
- Cottus gobio *predominantly occurs in stony streams and rivers where the flow is moderate and the water is cool and oxygen rich. In the Great Lakes, temperatures vary from season to season and flow is reduced.*
- *The Ponto-Caspian (Caspian, Azov, and Black Seas) have similar climate and surface water temperature ranges as the Great Lakes (Grigorovich et al. 2003, Reid and Orlova 2002, USEPA 2008).*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- Cottus gobio *lives in the Ponto-Caspian and the United Kingdom.*
- *Great Lakes underwent similar anthropogenic eutrophication as the Ponto-Caspian region (Reid and Orlova 2002). Surface water temperature is similar between the Great Lakes and Ponto-Caspian seas (Grigorovich et al. 2003, Reid and Orlova 2002, USEPA 2008).*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0
Unknown	U
	6

- *Water depth, moderate water flow, and cool water temperatures found in the Great Lakes during winter can provide suitable habitat for* Cottus gobio*.*
- Cottus gobio *requires various habitats according to its different life stages. Substrates with large stones appear essential for breeding, and leaf litter and macrophyte cover are preferred by adult fish (Tomlinson and Perrow 2003).*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0
Unknown	U
	0

- Cottus gobio *prefers cold water temperatures and moderate to high streamflow (Tomlinson and Perrow 2003).*
- Cottus gobio *individuals were put in three temperatures (6-10, 10-14, 14-18°C); a result from (T3) indicate that 8°C rise in water temperature disrupted the gonadal maturation in both gender (Dorts et al. 2012). The findings of the study suggest that exposure to elevated temperature within the context of climate worming might affect the reproductive success of* Cottus gobio *(Dorts et al. 2012).*
- *Reyjol et al. (2009) did a study on water temperature and* Cottus gobio *life history traits and reproduction. The results suggest that a mean air warming of 3.7° is enough to negatively impact* C. gobio *populations.*

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that	3

may be considered potential food items—are abundant and/or search time is moderate to high)	
Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
	6

- *The diet of* Cottus gobio *changes with the seasons and the availability of different food items. Generally crustaceans are taken in the winter months and a wide range of insect larvae in the summer; feeding activity takes place at dusk and perhaps also at night (Tomlinson and Perrow 2003).*
- Cottus gobio *feeds on benthic invertebrates (Smyly 1957). In the winter,* Gammarus *amphipods were a large component of their diet (Mills and Mann 1983), and in the summer, these fish hit their peak consumption of Plecoptera nymphs.These prey items occur in the Great Lakes.*

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Great Lakes and is not likely to be introduced	-80% total points (at end)
Unknown	U
	9

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established	6

and spread in the Great Lakes)	
Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0
Unknown	U
	0

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0
Unknown	U
	-20%

- *Larger fish (>75 g) and crayfish have a detrimental effect on bullhead population through competition for shelter, food, and direct predation; however, bullhead can co-exist with predators provided sutiable refuges are available (Tomlinson and Perrow 2003).*
- Cottus gobio *may be preyed on by some fish that occur in the Great Lakes including* Salmo trutta *and* Esox lucius *(Fuller et al. 2014, Fuller 2013).*

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9
Frequent, moderate inocula	6
Frequent, small inocula OR infrequent, large inocula	3
Infrequent, small or moderate inocula	0

Unknown	U
	U

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
	5

- Cottus gobio *probably colonized England when Britain was connected to mainland Europe during the last ice age. The explanation for its current distribution includes natural headwater capture and possibly human introduction (Tomlinson and Perrow 2003).*
- *This species is widespread in Europe. Its native range includes the Ponto-Caspian basin, the Baltic Sea basin, and the Iberian Peninsula (Vila-Gispert et al. 2005, Mann et al. 1984). It has extended its range to the south-eastern Pyrenees watershed, the Netherlands, and Germany. It seems that the spread of* Cottus gobio *is currently restricted to middle to eastern Europe.*

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
	U

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no	-90% total

reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing the establishment and spread of this species)	points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent the establishment and/or spread of this species	0
Unknown	U
	0

- *No control methods are known to be present in the Great Lakes for* Cottus gobio.

Establishment Potential Scorecard				
Points	**Probability for Establishment**	A. Total Points (pre-adjustment)		68
>100	High	**Adjustments**		
		B. Critical species	A*(1 - 0%)	68
51-99	Moderate	C. Natural enemy	B*(1 - 20%)	54.4
		Control measures	C*(1 - 0%)	54.4
0-50	Low	**Potential for Establishment**		Moderate
# of questions answered as "unable to determine"	**Confidence Level**			
0-1	High	Total # of questions unknown		2
2-5	Moderate			
6-9	Low	Confidence Level		Moderate
>9	Very low			

Section C: Potential for Impact

IMPACT POTENTIAL RESULTS

Environmental: Unknown

Socio-Economic: Low

Beneficial: Low

Current research on the potential for environmental impacts to result from *Cottus gobio* if introduced to the Great Lakes is inadequate to support proper assessment.

There is insufficient information available to determine whether *Cottus gobio* poses a threat to other species or water quality. There are no reports on how it affects or interacts with other species. It is unknown whether this species alters the physical components of the ecosystem.

Phyllodistomum folium is a parasite of *Cottus gobio* (Smyly 1957) and infects the urinary bladder (Dawes 1968). Three-spined sticklebacks, ruffe, grayling, and pike are also hosts of this parasite. *Phyllodistomum folium* has been found in central Europe, Sweden, and Canada. *Phyllodistomum folium* has been recorded in one specimen of pike in Lac Hertel of the Saint-Lawrence Valley, and has a limited occurrence (Todd 1963). There is no indication that *Phyllodistomum folium* is currently a threat for the Great Lakes species or will become a threat with the introduction of *Cottus gobio*.

There is little or no evidence to support that *Cottus gobio* has the potential for significant socio-economic impacts if introduced to the Great Lakes.

It has not been reported that *Cottus gobio* poses a threat to human health or water quality. There is no evidence that this species negatively impacts infrastructure, economic sectors, recreational activities and associated tourism, or the aesthetic appeal of the areas it inhabits.

There is little or no evidence to support that *Cottus gobio* has the potential for significant beneficial impacts if introduced to the Great Lakes.

It has not been indicated that *Cottus gobio* can be used for the control of other organisms or improving water quality. There is no evidence to suggest that this species is recreationally or medically valuable. It does not have significant positive ecological impacts. *Cottus gobio* can be eaten or used as live bait for large fish (Tomlinson and Perrow 2003).

POTENTIAL ENVIRONMENTAL IMPACT

NOTE: In this section, a “Not significantly” response should be selected if the species has been studied but there have been no reports of a particular impact. An “Unknown” response is appropriate if the species is poorly studied.

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1
Not significantly	0
Unknown	U √

- *There is no evidence that* Cottus gobio *is a hazard or threat to the health of native species.*

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1
Not significantly	0
Unknown	U √

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in the food web)	6
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	1
Not significantly	0
Unknown	U √

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0
Unknown	U √

- *No data were found that show genetic effects of* Cottus gobio *on native populations.*

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1
Not significantly	0
Unknown	U √

- *There was no evidence of* Cottus gobio *affecting water quality.*

E6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1
Not significantly	0
Unknown	U √

Environmental Impact Total	**0**
Total Unknowns (U)	**6**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	Low
1	0	
0	≥2	**Unknown**
1	≥1	

POTENTIAL SOCIO-ECONOMIC IMPACT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1
Not significantly	0 √
Unknown	U

- *There was no evidence of* Cottus gobio *species posing a hazard or threat to human health.*

S2) Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1
Not significantly	0 √
Unknown	U

S3) Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0 √
Unknown	U

S4) Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

Socio-Economic Impact Total	0
Total Unknowns (U)	0

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**Low**
1	0	
0	≥2	Unknown
1	≥1	

POTENTIAL BENEFICIAL EFFECT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular effect. An "Unknown" response is appropriate if the potential for a particular effect might be inferred but has not been explicitly reported or if there is an unresolved debate about a particular effect.

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1
Not significantly	0 √
Unknown	U

B2) Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?

Yes, it is economically important to at least one of these industries	6
Yes, but its economic contribution is small	1
Not significantly	0 √
Unknown	U

- Cottus gobio *was once eaten recreationally for its flavor and also used as live bait for larger fish species (Tomlinson and Perrow 2003).*

B3) Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local	6

communities and/or tourism	
It is sometimes employed recreationally, but adds little value to local communities or tourism	1
Not significantly	0 √
Unknown	U

B4) Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR It is potentially important to medicine or research and is currently being or scheduled to be studied	1
Not significantly	0 √
Unknown	U

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1
Not significantly	0 √
Unknown	U

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1
Not significantly	0 √
Unknown	U

Beneficial Effect Total	**0**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate

0	0-1	**Low**
1	0	
0	≥2	Unknown
1	≥1	

Scientific Name: *Ctenopharyngodon idella*
Valenciennes in Cuvier and Valenciennes, 1844

Common Name: Grass Carp

Synonyms:

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: High

Hitchhiking/fouling: Unlikely

Unauthorized intentional release: Moderate

Stocking/planting/escape from recreational culture: Moderate

Escape from commercial culture: Low

Transoceanic shipping: Unlikely

***Ctenopharyngon idella* has a high probability of introduction to the Great Lakes (Confidence level: High).**

Potential pathway(s) of introduction: Dispersal, Unauthorized Intentional Release, Unauthorized Stocking, Escape from Commercial Culture

Asian Carp introduced to the Mississippi River basin via escape from aquaculture, are identified as having high probability of invasion if introduced to the Great Lakes (Herborg et al. 2007, Mandrak and Cudmore 2005, Rixon et al. 2005, USEPA 2008); and listed as having extensive invasion history (Nico et al. 2015, Gherardi et al. 2009, GISD 2005a). Potential pathway of introduction: Inter-basin connections. NOTE: Grass Carp collected in the Great Lakes have been an illegally released, non-reproductive triploid variety.

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100 √
No, this species does not occur near waters connected to the Great Lakes basin and/or is not mobile or able to be transported by wind or water.	0
Unknown	U

- *Grass Carp individuals have been found in the Great Lakes but have not shown evidence of reproduction or establishment (Rixon et al. 2005).*

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1 √
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25
Unknown	U

- *Grass Carp individuals have been found in the Great Lakes but have not shown evidence of reproduction or establishment (Rixon et al. 2005).*
- *The United States Army Corps of Engineers (USACE) constructed a set of three electrical barriers, the first of which opened in 2002, on the Chicago Sanitary and Shipping Canal to prevent the spread of aquatic invasive species between the Great Lakes and Mississippi River basins (Baerwaldt et al. 2013). While this barrier will impede the spread of Grass Carp from the Mississippi River basin, Grass Carp has also be reported in waters around the Great Lakes basin (i.e. not influenced by these barriers).*

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0 √
Unknown	U

- *This species is not known to be transported by attaching to recreational equipment.*

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a) Is this species sold at aquarium/pet/garden stores (“brick & mortar” or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100 √
No, this species this species is rarely/never sold.	0
Unknown	U

- *This species was recorded to be found in three of the six live markets near Lakes Erie and Ontario (Rixon et al. 2005). Also, it was sold under names such as Chinese Buffalo and China Cardfish so individuals may not be aware they have a potential invader.*

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5 √
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1
Unknown	U

- *An online search several stores that ship triploids to the Great Lakes States.*
- *The 2005 study by Rixon found this species for sale at markets near Lakes Erie and Ontario. While surveillance has likely increased, there is no evidence that Grass Carp is no longer for sale.*

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100 √
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0
Unknown	U

- *Michigan is allowed to have eggs for research, but surrounding states are allowed to stock triploid Grass Carp (Conover 2007).*

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75 √
This activity is likely to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces), this activity may occur within 20 km of the basin because of the species' popularity/value.	Score x 0.25
Unknown	U

- *Grass Carp were illegally stocked in Michigan (Emery 1985).*

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100 √
No, this species is not commercially cultured in or transported through the Great Lakes region.	0
Unknown	U

- *This species is cultured in states surrounding the Great Lakes (Conover 2007).*

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25 √
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U

- *Very few states have no regulations and allow diploid Grass Carp, and the majority either restrict both or allow triploid nonreproductive Grass Carp (Conover 2007).*

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40
No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0 √
Unknown	U

- *Grass Carp are not known to be taken up through ballast.*

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5
Yes, but this species has neither been observed in ballast/fouling ships entering the Great Lakes nor in ports in direct trade with the Great Lakes.	Score x 0.1
No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0
Unknown	U

Vector Potential Scorecard					
Vector		**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind		**100**	x 1	**100**	High
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.		**0**	x	**0**	Unlikely
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)		**100**	x 0.5	**50**	Moderate
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)		**100**	x 0.75	**75**	Moderate
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)		**100**	x 0.25	**25**	Low
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling		**0**	x	**0**	Unlikely
Total Unknowns (U)	**0**	**Confidence Level**		High	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low

0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

ESTABLISHMENT POTENTIAL RESULTS

Status: Established in North America, but not the Great Lakes

***Ctenopharyngon idella* has a moderate probability of establishment if introduced to the Great Lakes (Confidence level: High).**

The climate of the Great Lakes region is suitable for *Ctenopharyngon idella*. They tolerate temperature minimums to 4^oC (Herborg et al. 2007) so would have no difficulty overwintering. To the contrary, they have shown to have an ecological advantage for migrating to habitats with rapid temperature changes (Zhao et al. 2011). Spawning requires flowing rivers with a higher temperature – conditions which are met in only a few areas of the Great Lakes, but these areas are capable of producing fish which would then migrate throughout the system (Schofield et al. 2005).

Grass Carp are obligate herbivores, eating massive quantities of aquatic plants (Petr and Mitrofanov 1998). This diet preference may restrict them to the shallower littoral zones and coastal wetlands of the Great Lakes, where suitable food is plentiful. They are known to be successful competitors against native fishes (USEPA 2008).

Current regulations and control measures are in place which are somewhat likely to be effective in preventing the establishment of Grass Carp in the Great Lakes.

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
	7

- *Grass Carp have shown to have an ecological advantage for migrating to habitats with rapid temperature changes (Zhao et al. 2011).*

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9
Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
	8

- *Minimum temperature range is from -11–4˚C (Herborg et al. 2007).*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
	4

- *Grass Carp are a strictly herbivorous species that has an intense grazing activity over aquatic vegetation (Petr and Mitrofanov 1998).*

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	0

Unknown	U
	8

- *Has known to destroy existing food chain relationships and threatens the spawning grounds of native fish when in excessive numbers (Petr and Mitrofanov 1998).*
- *Grass Carp are known to compete with native fish and have a history of invasion throughout the United States (USEPA 2008).*

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
	5

- *Spawning occurs at water temperatures between 17-26˚C and more commonly occurs in large flowing rivers. Fecundity has been found to range widely from 2555,000-2,000,000 eggs (Schofield et al. 2005).*

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
	0

- *Spawning is required in flowing rivers with a higher temperature and is needed for success in early development, only a few areas in the Great Lakes can provide this type of environment for spawning by the Grass Carp (Schofield et al. 2005).*

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	9

- *Grass Carp native region of Eastern Asia is very similar to that of the United States with a temperate climate, warm summers and cold winters.*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	5

- *Spawning is required in flowing rivers with a higher temperature and is needed for success in early development, only a few areas in the Great Lakes can provide this type of environment for spawning in the Grass Carp (Schofield et al. 2005).*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0
Unknown	U
	6

- *It is estimated around 91-100% environmental suitability throughout a majority of the United States and about half of Canada (Herborg et al. 2007).*

- *Spawning is required in flowing rivers with a higher temperature and is needed for success in early development, only a few areas in the Great Lakes can provide this type of environment for spawning in the Grass Carp (Schofield et al. 2005).*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0
Unknown	U
	9

- *The effects of climate change would most likely help the establishment of the Grass Carp in the Great Lakes and allow it to spread throughout all 5 (Mandrak 1989).*

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
	7

- *There appears to be no restrictions on food; Grass Carp are very diverse feeders, feeding on a majority of aquatic vegetation.*

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the	9

Great Lakes and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Great Lakes and is not likely to be introduced	-80% total points (at end)
Unknown	U
	9

- *There is no critical species required for the critical stages of the Grass Carp life cycle.*

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes)	6
Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0
Unknown	U
	0

- *The establishment of this species will not be aided by an establishment of another species.*

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	-80% total points (at end)

Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0
Unknown	U
	0

- *There is bacteria that can kill the Grass Carp but they are transmitted through Bighead and Silver Carp which are not found in the Great Lakes (Kolar et al. 2005).*

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9
Frequent, moderate inocula	6
Frequent, small inocula OR infrequent, large inocula	3
Infrequent, small or moderate inocula	0
Unknown	U
	4

- *There have been recorded catches of the Grass Carp in Lake Michigan, Huron, and Erie (Rixon et al. 2005).*
- *Grass Carp has been found isolated in Lake Erie, Huron, Ontario (USEPA 2008).*

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
	9

- *Grass Carp were established in numerous states in 1993, 30 years after its initial release in Arkansas (DeVaney et al. 2009).*

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
	9

- *After being stocked in the Volga River it took 7 years for a reproducing population and after introduction in the Amu-Darya River it had a reproducing population within a year (Stanley 1976).*

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing the establishment and spread of this species)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent the establishment and/or spread of this species	0
Unknown	U
	-40%

- *The Asian Carp management and control plans can used for Grass Carp.*
- *The Asian Carp Control Strategy Framework can used for Grass Carp.*
- *The Asian Carp Regional Coordinating Committee can used for Grass Carp.*
- *The Asian Carp Monitoring and Rapid Response Plan can used for Grass Carp.*
- *eDNA monitoring can used for Grass Carp.*

Establishment Potential Scorecard			
Points	**Probability for Establishment**	A. Total Points (pre-adjustment)	99
>100	High	**Adjustments**	

		B. Critical species	A*(1- 0%)	99
51-99	Moderate	C. Natural enemy	B*(1- 0%)	99
		Control measures	C*(1- 40%)	59.4
0-50	Low	**Potential for Establishment**		Moderate
# of questions answered as “unable to determine”	**Confidence Level**			
0-1	High	Total # of questions unknown		0
2-5	Moderate			
6-9	Low	Confidence Level		High
>9	Very low			

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High
1-2	Moderate
3-5	Low
>5	Very low

Section C: Potential for Impact

IMPACT POTENTIAL RESULTS

Environmental: High

Socio-Economic: Low

Beneficial: High

***Ctenopharyngon idella* has the potential for high environmental impact if introduced to the Great Lakes.**

Grass Carp have environmental impacts on the ecosystems they have been introduced. For instance, Grass Carp is known to be the source of major alterations to the trophic structure and food chains of aquatic systems. Many of these changes in plant, invertebrate and fish communities are largely secondary consequences of reductions in the density and composition of aquatic plant communities (Bain 1993, Cudmore and Mandrak 2004). When stocked at high densities, Grass Carp can eliminate all vegetation in even large aquatic systems (e.g., 8100-ha Lake Conroe, Klussman et al. 1988). Declines have occurred in the diversity and density of organisms that are dependent on structured littoral habitats and food chains based on plant detritus, macrophytes, and attached algae as a consequence of reduced plant surface habitat, increased invertebrate food supplies (i.e. plant detritus), altered substrate conditions, and increased dissolved oxygen conditions (Bain 1993, Martin and Shireman 1976, Vinogradov and Zolotova 1974).

Ctenopharyngodon idella is known to out-compete native species for both food and habitat. Research in small closed systems has demonstrated that due to Grass Carp's preference for native aquatic plants over milfoil, these fish compete with waterfowl, which feed on these plants as well (Fowler and Robson 1978, McKnight and Hepp 1995, Pine et al. 1990, Pine and Anderson 1991). Furthermore, direct competition for plant material also occurs between Grass Carp and other herbivorous fishes, such as forage fishes (Cudmore and Mandrak 2004). Grass Carp may compete with planktonic and benthic species, including catfishes and hybrid sunfishes for aquatic plants (Shireman and Smith 1983), especially during Grass Carp juvenile stages and at lower water temperatures (Fedorenko and Fraser 1978). Direct competition for habitat has been found to occur between Grass Carp and other fish species, particularly bluegill. With their schooling habit, Grass Carp constantly invade and disturb bluegill spawning areas, consequently greatly reducing Bluegill weight and numbers (Forester and Lawrence 1978).

Grazing by Grass Carp has been associated with alterations of water quality. The decay of these large volumes of dead aquatic plants due to Grass Carp's grazing and waste production elevate nutrient levels in water, induce phytoplankton blooms, reduce water clarity, and decrease oxygen levels (Bain 1993, Boyd 1971, Vinogradov and Zolotova 1974).

Cyprinids, including Grass Carp, are known to be carriers of numerous parasitic organisms. Shireman and Smith (1983) thoroughly list a wide array of organisms, from viruses to protozoans to trematodes, that are parasites of Grass Carp. Worth noting is *Bothriocephalus acheilognathi*, the Asian Tapeworm. This parasite has been introduced by cyprinids, particularly by its native host the Grass Carp, to every continent except Antarctica (Bain 1993, Salgado-Maldonado and Pineda-Lopez 2003). Additionally, Grass Carp are the source of Ergacilus spp. in United Kingdom waters (Cowx 1997). However, disease and parasitism are not as prevalent in wild populations as in fish culture (Shireman and Smith 1983).

There is little or no evidence to support that *Ctenopharyngon idella* has the potential for significant socio-economic impacts if introduced to the Great Lakes.

It has not been reported that *Ctenopharyngon idella* poses a threat to human health or water quality. There is no evidence that this species negatively impacts infrastructure, economic sectors, recreational activities and associated tourism, or the aesthetic appeal of the areas it inhabits. One of the undesirable consequences of stocking Grass Carp is increased turbidity, either algal or abiotic (Bonar et al. 2002, Lembi et al. 1978, Maceina et al. 1992, Water Environmental Services Incorporated 1994). When in excessive numbers it can destroy existing food chain relationships and threatening the spawning grounds of commercial fishes (Petr and Mitrofanov 1998).

***Ctenopharyngon idella* has the potential for high beneficial impact if introduced to the Great Lakes.**

Because of its strong preference for aquatic vegetation, ability to be cultured easily, and hardiness, Grass Carp is being widely introduced throughout the United States to control aquatic vegetation in lakes and ponds (Chilton and Muoneke 1992, Page and Burr 1991). Grass Carp can effectively control and eliminate aquatic plants in a variety of situations. Private fish farms have been producing large numbers of sterile, triploid Grass Carp as interest in stocking open systems increases (Bain 1993). Grass Carp also are now routinely stocked in irrigation canals of the western United States (Bain 1993) and in Saskatchewan, Canada (Cudmore and Mandrak 2004).

Despite its bony flesh, Grass Carp is consumed as food in many regions of the world (Opuszynski and Shireman 1995) and are fished in some areas in their native range (Shireman and Smith 1983). However, they rarely comprise a large proportion of the catch and are taken incidentally in common or silver carp fisheries in the Amur basin (Shireman and Smith 1983). In the United States, Grass Carp has been harvested Mississippi River in Missouri throughout the 1990s (Pflieger 1997) and by 1996, it accounted for 8% of the total commercial fish harvest from this area (Cudmore and Mandrak 2004, USGS 2012).

POTENTIAL ENVIRONMENTAL IMPACT

NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1 √
Not significantly	0
Unknown	U

- *Cyprinids, including Grass Carp, are known to be carriers of numerous parasitic organisms. Shireman and Smith (1983) thoroughly list a wide array of organisms, from viruses to protozoans to trematodes, that are parasites of Grass Carp. Worth noting is* Bothriocephalus acheilognathi*, the Asian tapeworm. This parasite has been introduced by cyprinids, particularly by its native host the Grass Carp, to every continent except Antarctica (Bain 1993, Salgado-Maldonado and Pineda-Lopez 2003). Additionally, Grass Carp are the source of* Ergacilus *spp. in United Kingdom waters (Cowx 1997). However, disease and parasitism are not as prevalent in wild populations as in fish culture (Shireman and Smith 1983).*

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1 √
Not significantly	0
Unknown	U

- Ctenopharyngodon idella *is known to out-compete native species for both food and habitat. Research in small closed systems has demonstrated that due to Grass Carp's preference for native aquatic plants over milfoil, these fish compete with waterfowl, which feed on these plants as well (Fowler and Robson 1978, McKnight and Hepp 1995, Pine et al. 1990, Pine and Anderson 1991). Furthermore, direct competition for plant material also* *occurs between Grass Carp and other herbivorous fishes, such as forage fishes (Cudmore and Mandrak 2004). Grass Carp may compete with planktonic and benthic species, including catfishes and hybrid sunfishes for aquatic plants (Shireman and Smith 1983), especially during Grass Carp juvenile stages and at lower water temperatures (Fedorenko and Fraser 1978).*

- *On the other hand, direct competition for habitat has been found to occur between Grass Carp and other fish species, particularly bluegill. With their schooling habit, Grass Carp constantly invade and disturb bluegill spawning areas, consequently greatly reducing bluegill weight and numbers (Forester and Lawrence 1978).*

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in the food web)	6 √
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	1
Not significantly	0
Unknown	U

- *Grass Carp have environmental impacts on the ecosystems they have been introduced. For instance, Grass Carp is known to be the source of major alterations to the trophic structure and food chains of aquatic systems. Many of these changes in plant, invertebrate and fish communities are largely secondary consequences of reductions in the density and composition of aquatic plant communities (Bain 1993, Cudmore and Mandrak 2004). When stocked at high densities, Grass Carp can eliminate all vegetation in even large aquatic systems (e.g., 8100-ha Lake Conroe, Klussman et al. 1988). Declines have occurred in the diversity and density of organisms that are dependent on structured littoral habitats and food chains based on plant detritus, macrophytes, and attached algae as a consequence of reduced plant surface habitat, increased invertebrate food supplies (i.e. plant detritus), altered substrate conditions, and increased dissolved oxygen conditions (Bain 1993, Martin and Shireman 1976, Vinogradov and Zolotova 1974).*

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0
Unknown	U √

- *There has been no evidence of it affecting native populations genetically.*

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6 √
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1
Not significantly	0
Unknown	U

- *Grazing by Grass Carp has been associated with alterations of water quality. The decay of these large volumes of dead aquatic plants due to Grass Carp's grazing and waste production elevate nutrient levels in water, induce phytoplankton blooms, reduce water clarity, and decrease oxygen levels (Bain 1993, Boyd 1971, Vinogradov and Zolotova 1974).*

E6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6 √
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1
Not significantly	0
Unknown	U

- *The herbivorous Grass Carp has a significant impact on macrophyte communities through intense grazing pressure (Bain 1993).*

Environmental Impact Total	**20**
Total Unknowns (U)	**1**

Scoring		
Score	# U	Impact
>5	Any	**<u>High</u>**
2-5	Any	Moderate
0	0-1	Low
1	0	
0	≥2	Unknown
1	≥1	

<u>POTENTIAL SOCIO-ECONOMIC IMPACT</u>

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1
Not significantly	0 √
Unknown	U

- *There has been no evidence showing hazardous threats to human health by the Grass Carp.*

S2) Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1
Not significantly	0 √
Unknown	U

- *There has been no evidence showing damage to infrastructure by the Grass Carp.*

S3) Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0 √
Unknown	U

- *One of the undesirable consequences of stocking Grass Carp is increased turbidity, either algal or abiotic (Bonar et al. 2002, Lembi et al. 1978, Maceina et al. 1992, Water Environmental Services Incorporated 1994).*

S4) Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1 √
Not significantly	0
Unknown	U

- *When in excessive numbers it destroys existing food chain relationships and threatening the spawning grounds of commercial fishes (Petr and Mitrofanov 1998).*

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

- *There is no evidence provided that it inhibits recreational activities.*

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

Socio-Economic Impact Total	**1**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**Low**
1	0	
0	≥2	Unknown
1	≥1	

POTENTIAL BENEFICIAL EFFECT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular effect. An "Unknown" response is appropriate if the potential for a particular effect might be inferred but has not been explicitly reported or if there is an unresolved debate about a particular effect.

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6 √
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired	1

level of effectiveness	
Not significantly	0
Unknown	U

- *Because of its strong preference for aquatic vegetation, ability to be cultured easily, hardiness and good flavor, Grass Carp is being widely introduced throughout the United States to control aquatic vegetation in lakes and ponds (Chilton and Muoneke 1992, Page and Burr 1991). Grass Carp can effectively control and eliminate aquatic plants in a variety of situations. Private fish farms have been producing large numbers of sterile, triploid Grass Carp as interest in stocking open systems increases (Bain 1993). Grass Carp also are now routinely stocked in irrigation canals of the western United States (Bain 1993) and in Saskatchewan, Canada (Cudmore and Mandrak 2004).*

B2) Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?

Yes, it is economically important to at least one of these industries	6
Yes, but its economic contribution is small	1 √
Not significantly	0
Unknown	U

- *Despite its bony flesh, Grass Carp is consumed as food in many regions of the world (Opuszynski and Shireman 1995) and are fished in some areas in their native range (Shireman and Smith 1983). However, they rarely comprise a large proportion of the catch and are taken incidentally in common or silver carp fisheries in the Amur basin (Shireman and Smith 1983). In the United States, Grass Carp has been harvested Mississippi River in Missouri throughout the 1990s (Pflieger 1997) and by 1996, it accounted for 8% of the total commercial fish harvest from this area (Cudmore and Mandrak 2004, USGS 2012).*

B3) Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local communities and/or tourism	6
It is sometimes employed recreationally, but adds little value to local communities or tourism	1 √
Not significantly	0
Unknown	U

- *Grass Carp are frequently used for prayer release (freeing captive animals into the wild as a form of prayer to accrue merits (Crossman and Cudmore 1999a, 1999b; Severinghaus and Chi 1999); these individuals can then be caught by recreational fisherman (Cudmore and Mandrak 2004).*

B4) Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR It is potentially important to medicine or research and is currently being or scheduled to be studied	1
Not significantly	0 √
Unknown	U

- *There has been no real significant medicinal or research value of the Grass Carp.*

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1
Not significantly	0 √
Unknown	U

- *There has been no evidence showing Grass Carp removes pollutants from the water.*

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1
Not significantly	0 √
Unknown	U

- *Grass Carp have shown to destroy existing food chain relationships and threatening the spawning grounds of commercial fishes in excessive numbers (Petr and Mitrofanov 1998).*
- *Grass Carp are known to be vectors for B. acheilognathi which have been known to infect and kill native species (Kolar et al. 2005).*
- *Grass Carp have negative impacts on phytoplankton, invertebrate communities, and native fish (Herborg et al. 2007).*

Beneficial Effect Total	**8**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	<u>**High**</u>
2-5	Any	Moderate
0	0-1	Low
1	0	Low
0	≥2	Unknown
1	≥1	Unknown

Scientific Name: *Cyprinella whipplei*
Girard, 1856

Common Name: Steelcolor Shiner

Synonyms:

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: Moderate

Hitchhiking/fouling: Unlikely

Unauthorized intentional release: Unlikely

Stocking/planting/escape from recreational culture: Unlikely

Escape from commercial culture: Unlikely

Transoceanic shipping: Unlikely

***Cyprinella whipplei* has a moderate probability of introduction to the Great Lakes (Confidence level: High).**

Potential pathway(s) of introduction: Dispersal

Cyprinella whipplei occurs in the Mississippi River basin, Ohio River, Muskingum River, and the Fox River drainage, which are near waters connected to the Great Lakes basin (Page and Burr 1991, Retzer and Batten 2005, Sanders 1992). There are electrical barriers between the Great Lakes and Mississippi River basins that function to prevent the spread of aquatic invasive species (Rasmussen et al. 2011). There is no evidence that suggests that *Cyprinella whipplei* is capable of hitchhiking or fouling ships. There are no records of the stocking, culture, or sale of *Cyprinella whipplei* in the Great Lakes region.

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100 √
No, this species does not occur near waters connected to the Great Lakes basin and/or is not mobile or able to be transported by wind or water.	0
Unknown	U

- *The Steelcolor Shiner Minnow occurs in spots throughout the Mississippi River basin extending up to the northern borders of the Great Lakes basin including the upper and middle Ohio River basin, spanning Ohio, Indiana, and Illinois (Page and Burr 1991).*
- Cyprinella whipplei *occurs in the Ohio and Muskingum Rivers near Marietta, Ohio (Sanders 1992).*
- C. whipplei *occurs in the Fox River drainage near Chicago, Illinois (Retzer and Batten 2005).*
- *The Steelcolor Shiner Minnow is mobile and able to swim through small bodies of water and streams if environmental conditions are not lethal (Gibbs 1963).*
- *There are electrical barriers between the Great Lakes and Mississippi River basins that function to prevent the spread of aquatic invasive species (Rasmussen et al. 2011).*

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75 √
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25
Unknown	U

- *Though barriers do exist in various locations in rivers that do and could harbor the Steelcolor Shiner Minnow (Sparks 2010), it is widespread enough to have true access if other variables were suitable (Schönhuth and Mayden 2010, Taylor 2000).*
- *The Steelcolor Shiner Minnow prefers the larger pools of quicker upland riverine habitats (Hocutt and Wiley 1986). These areas are prevalent on all outside borders of the Great Lakes basin as well as within it.*
- *This species has been found in the Ohio and Muskingum Rivers near Marietta, Ohio, which is approximately 260 kilometers from Lake Erie (Sanders 1992).*
- *This species occurs in the Fox River drainage near the Chicago, Illinois region (Retzer and Batten 2005). Fox River is about 65 kilometers from Lake Michigan.*

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0 √
Unknown	U

- *Being a fish, the Steelcolor Shiner Minnow is not likely, in any part of its life cycle, to attach to surfaces (Gibbs 1963).*
- *Though not likely or often, there is some possibility of fish or fish egg transport via natural (e.g., bird) or human (e.g., bait bucket) means.*

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1
Unknown	U

- *The Steelcolor Shiner Minnow is not currently listed in Michigan's fish surveys; however, under its previous taxonomic name of* Notropis whipplii*, it is listed as a common minnow of Michigan waters (Hubbs and Cooper 1936). More phylogenetic and taxonomical research would be necessary to establish whether this particular minnow was ever present in the Great Lakes basin as a native species.*

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a) Is this species sold at aquarium/pet/garden stores ("brick & mortar" or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100
No, this species this species is rarely/never sold.	0 √
Unknown	U

- *The Steelcolor Shiner Minnow being raised, kept, or sold as a bait fish like other minnows is a possibility, there is no known record of it occurring (INDNR 2013, Willoughby 1965, Yoder 1954).*
- *The Steelcolor Shiner Minnow is not sold legally or on the "black market" (INDNR 2013).*

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0 √
Unknown	U

- *There is no known instance of the Steelcolor Shiner Minnow being stocked or grown for food, bait, or recreational purposes in or around the Great Lakes region (INDNR 2013).*

- *Though the Steelcolor Shiner could be used as bait or stock for ponds, it is not listed in commercial listings or as prohibited for aquaculture sales (MacNeill et al. 2009). It is thought that this fish is not hardy enough for this purpose (Mayden 2003).*

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is likely to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces), this activity may occur within 20 km of the basin because of the species' popularity/value.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100
No, this species is not commercially cultured in or transported through the Great Lakes region.	0 √
Unknown	U

- *Though the Steelcolor Shiner Minnow is not often grown or sold as bait or food, the mere proximity of this fish does allow for transport. No record was found of the steelcolor shiner minnow being transported (MIDNR 2013).*
- *The Steelcolor Shiner Minnow is not a prohibited fish for transport (MacNeill et al. 2009).*
- *The Steelcolor Shiner Minnow is located in streams near the border of the Great Lakes basin and could be transported by individuals; however there is no record of this (Schönhuth and Mayden 2010).*

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40
No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0 √
Unknown	U

- *For several reasons already discussed above, such as specific riverine habitats and delicate survival needs, it is unlikely that the Steelcolor Shiner Minnow would be incorporated into the ballast of large ships as a vector for transport (Britton et al. 2010, Clavero and Garcia-Berthou 2006, Gozlan et al. 2010b).*

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5
Yes, but this species has neither been observed in ballast/fouling ships entering the Great Lakes nor in ports in direct trade with the Great Lakes.	Score x 0.1
No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0
Unknown	U

Vector Potential Scorecard				
Vector	**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind	**100**	x 0.75	**75**	Moderate
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.	**0**	x	**0**	Unlikely
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)	**0**	x	**0**	Unlikely

Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)	**0**	x	**0**	Unlikely
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)	**0**	x	**0**	Unlikely
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling	**0**	x	**0**	Unlikely
Total Unknowns (U)	**0**	**Confidence Level**	High	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

ESTABLISHMENT POTENTIAL RESULTS

Status: **Established in North America, but not the Great Lakes**

Cyprinella whipplei **has a moderate probability of establishment if introduced to the Great Lakes (Confidence level: Moderate).**

Cyprinella whipplei has a wide temperature tolerance, and has been reported to occur in streams with temperatures as low as -0.5°C (Felley and Hill 1983) to temperatures as high as 25°C (Risch 2004). This species is somewhat likely to overwinter in the Great Lakes region due to its ability to tolerate low temperature waters and its current geographical range that extends to Illinois and Ohio. It is native to the Alabama and Louisiana, so warmer water temperatures and shorter ice cover may aid the establishment of *Cyprinella whipplei*. It inhabits streams of varying sizes with sand or gravel bottoms and permanent flows (Ross 2001). This species reproductive behavior involves the use of crevices in submerged logs (Pflieger 1965). These habitats are available in the Great Lakes basin.

Cyprinella whipplei may have a low tolerance to habitat degradation. This species once occurred throughout central Illinois, but has retreated eastwards (Smith 2002). Its retreated distribution has been attributed to increasing siltation, removal of riparian vegetation, and the deterioration of water quality, as well as its inability to compete with the red shiner and spotfin shiner. *Cyprinella whipplei* was found in fish surveys conducted in 2008 in Killbuck Creek and Pipe Creek, Indiana, but were absent in 1978 (Doll 2010). Since the 1978 survey, there has been an effort to increase the area of wetland coverage in Indiana, although there has been some clear cutting of the riparian zone in 1998. It is possible that *Cyprinella whipplei* was able to establish in these areas since 1978 due to increased habitat quality.

Cyprinella whipplei feeds on macroinvertebrates such as aquatic and terrestrial insects, benthic invertebrates, crustaceans, mites, and earthworms (Ross 2001, Stauffer 2007). Its prey is readily available in the Great Lakes basin. Piscivorous animals such as gar, bass, sunfish, sturgeon, large chubs, kingfisher, heron, and turtles are known to feed on shiners (Mayden 2013 pers. comm.). These piscivores occur in the Great Lakes region (MDEQ 2008).

Cyprinella whipplei is established in Oklahoma (Fuller and Nico 2015a). A survey conducted by Fisher et al. (1998) in 1994 found that the historically uncommon *Cyprinella whipplei* had expanded its range in Tippecanoe County, Indiana since the mid-1970's. The 1978 survey collected 2 specimens of *Cyprinella whipplei*, and the 1994 survey collected 16 specimens; however, the authors note that the historically low abundance of *Cyprinella whipplei* could be attributed to misidentification of this species during the 1978 survey. Although historically present in Indiana, *Cyprinella whipplei* was first recorded in the Kankakee River drainage in 1990 (Simon et al. 1992). *Cyprinella whipplei* was found in fish surveys conducted in 2008 in Killbuck Creek and Pipe Creek, but were absent in 1978 (Doll 2010).

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
	3

- *Though widespread in the mid United States, the Steelcolor Shiner Minnow has a narrower habitat preference range than other species in its genus, and thus it is found in local "pockets" (Mayden 1989, Smith 2002, Trautman 1980).*
- *The Steelcolor Shiner Minnow prefers upland pools of quick moving riverine habitats, which are found in many areas of the Great Lakes; however, it is apparently not tolerant to extremes outside of this range, because it is not found in broad areas and immediately neighboring habitats (Doll 2010, Gibbs 1963, Hubbs and Cooper 1936, Schönhuth and Mayden 2010).*
- *That the Steelcolor Shiner Minnow has not been used to stock ponds or raised for bait purposes may indicate that it is not hardy under variable, non-native conditions or in situations of over-crowding or low biodiversity (INDNR 2013, MIDNR 2013, Willoughby 1965, Yoder 1954).*
- *This species has been recorded in streams with temperatures as low as -0.5°C (Felley and Hill 1983) and as high as 25.0°C (Risch 2004).*

- *This species has been found in streams that have 7.7 – 10.0 mg/L dissolved oxygen (Risch 2004).*
- Cyprinella whipplei *may have a low tolerance to habitat degradation. This species once occurred throughout central Illinois, but has retreated eastwards (Smith 2002). Its retreated distribution has been attributed to increasing siltation, removal of riparian vegetation, and the deterioration of water quality.* Cyprinella whipplei *was found in fish surveys conducted in 2008 in Killbuck Creek and Pipe Creek, Indiana, but were absent in 1978 (Doll 2010). Since the 1978 survey, there has been an effort to increase the area of wetland coverage in Indiana, although there has been some clear cutting of the riparian zone in 1998. It is possible that* Cyprinella whipplei *was able to establish in these areas since 1978 due to increased habitat quality.*

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9
Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
	5

- *Since the Steelcolor Shiner Minnow exists so close to the southern border of the Great Lakes basin in its normal range, it must be able to withstand some temperature ranges of winter. However, it has not infiltrated simultaneously with other species in the same genus over time (Doll 2010, Felley 1983, McAllister et al. 2010, Schönhuth and Mayden 2010, Taylor 2000).*
- *The phylogenetic differentiation of the* Cyprinella whipplei *and* Notropis spiloptera*, the Spotfin Shiner, that occurred after 1938 can indicate that the Steelcolor Shiner Minnow may be limited to a more southern range than the Spotfin Shiner (Gibbs 1957, Gibbs 1963, Mayden 1989, Schönhuth and Mayden 2010, Trautman 1980).*
- *This species has been found in streams that have 7.7 – 10.0 mg/L dissolved oxygen and at temperatures up to 25.0°C (Risch 2004).*
- *This species has been recorded in streams with temperatures as low as -0.5°C (Felley and Hill 1983).*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
	6

- *This fish feeds on aquatic and terrestrial insects, small crustaceans, mites, and earthworms (Stauffer 2007).*
- Cyprinella whipplei *generally feeds on insects in the water column, and changes its diet seasonally (Ross 2001). They feed on terrestrial insects that fall into the stream in the summer and fall.* Cyprinella whipplei *shifts to feeding on benthic invertebrates during colder weather. During the winter and spring, they also feed on organic detritus.*

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	0
Unknown	U
	5

- *Information and studies regarding the competitive abilities of* Cyprinella whipplei *are insufficient.*
- *In central Illinois, the distribution of* Cyprinella whipplei *had retreated to the eastern side of Illinois. This reduction in geographical range has been attributed to its inability to tolerate declining habitat quality (siltation, degradation of riparian zone, poor water quality), and its inability to compete with the Red Shiner and Spotfin Shiner (Smith 2002).*

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
	U

- *There is not much research on the quantity or survival rate of offspring for the Steelcolor Shiner Minnow. The reproductive method is described as crevice-spawning (Johnston 1999, Pflieger 1965), but more data would be needed for the approximate numbers of living offspring compared to other minnows of the same genus or how offspring numbers varied with environmental changes.*
- *Pflieger 1965 did note that* Notropis whipplii *did breed in aquaria habitats, which would demonstrate fecundity or hardiness but it is unknown now whether it was the renamed* Cyprinella whipplei *or* Notropis spiloptera *species.*

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment	9

in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
	0

- *There is literature based on the reproductive habits of the Steelcolor Shiner Minnow and it is described as crevice spawning (Hocutt and Wiley 1986, Johnston 1999, Pflieger 1965, Smith and Smith 1983). This minnow prefers habitat with fallen logs and branches in moderately moving river areas for breeding.*
- *The required breeding habitat for the Steelcolor Shiner Minnow, crevices in submerged logs and roots, is prevalent in the Great Lakes area. This species has not been documented to exhibit reproductive strategies (such as parthenogenesis, self-fertilization, or vegetative states) to improve reproductive success in sub-optimum environmental conditions.*
- *According to several sources describing the Steelcolor Shiner Minnow's reproductive method (Johnston 1999, Mayden and Simons 2003, Pflieger 1965), there is no indication it has any increase in hardiness over other minnows of the same genus and could even be less fit from simple observance of its distribution compared to other minnows of the same genus (Mayden 2013).*

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	7

- *This species occurs in central and eastern Illinois and Ohio, states that border the Great Lakes. This species has been recorded in streams with temperatures as low as -0.5°C (Felley and Hill 1983) and as high as 25°C (Risch 2004).*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9

Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- *Due to the proximity of the range limits of the Steelcolor Shiner Minnow's habitat and that of the Great Lakes basin, many of the abiotic factors of the two regions are the same. Suitable habitats for the Steelcolor Shiner Minnow are found in the Great Lakes basin.*
- *In several studies where the Steelcolor Shiner Minnow is native to a river system, the minnow shows mixed response to abiotic or environmental changes (Daulwater et al. 2008, Doll 2010, Felley 1983, Hocutt and Wiley 1986, Mandrak and Cudmore 2010, Pritchett and Pyron 2011). It is less tolerant to current and food choices and may exhibit lower fecundity if habitat is disturbed.*
- *It is shown that when there is a higher level of biodiversity, the Steelcolor Shiner Minnow is present and doing well, though never outcompeting other minnow species unless it hybridizes (Mandrak and Cudmore 2010).*
- *This species occurs in central and eastern Illinois and Ohio, states that border the Great Lakes. This species has been recorded in streams with temperatures as low as -0.5°C (Felley and Hill 1983) and as high as 25°C (Risch 2004).*
- Cyprinella whipplei *is a freshwater fish that inhabits rivers; salinity of its native and introduced ranges is very similar to the salinity ranges in the Great Lakes region.*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0
Unknown	U
	7

- *This species inhabits pools and riffles of low-to-moderate gradient streams with permanent flows (Ross 2001). These types of habitats are available in the Great Lakes region.*
- Cyprinella whipplei *uses crevices in submerged logs for reproduction (Pflieger 1965). It is likely that logs with crevices are somewhat abundant in the streams in the Great Lakes basin.*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6

Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0
Unknown	U
	7

- *The closest phylogenetic relatives of the Steelcolor Shiner Minnow, such as* Notropis spiloptera *exist in more Northern or colder regions (Doll 2010, Mayden 1989, Page and Burr 2011, Schönhuth and Mayden 2010), so the limiting factor for spread could be temperature tolerance.*
- *Given some inability to "hop" habitats and possibly pass through less hospitable habitats to spread its range, the steelcolor shiner minnow may benefit from a warmer winter season (Crossman and Cudmore 2000).*
- *There is no data on the Steelcolor Shiner Minnows increased or decreased success based on ice cover. It is a riverine minnow and may not tolerate completely surface-frozen conditions (Aadland and Kuitunen 2004, Clavero and Garcia-Berthou 2006).*
- *The Steelcolor Shiner Minnow may be limited or more successful in spreading to a new region based on changing streamflow patterns resulting from climate change. It is a stream and river minnow with specific habitat preferences, such as rate of current (Gozlan et al. 2010b, Hocutt and Wiley 1986, Trautman 1980), so altered stream flows will surely affect this fish. The nature of the effect is unknown.*
- *It is native to Alabama and Louisiana, so warmer water temperatures and shorter ice cover may aid the establishment of* Cyprinella whipplei.

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
	7

- Cyprinella whipplei *generally feeds on insects in the water column, and changes its diet seasonally (Ross 2001). They feed on terrestrial insects that fall into the stream in the summer and fall.* Cyprinella whipplei *shifts to feeding on benthic invertebrates during colder weather. During the winter and spring, they also feed on organic detritus. It preys on small crustaceans, mites, and earthworms (Stauffer 2007).*

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being	9

assessed; OR, No, there is no critical species required by the species being assessed	
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Great Lakes and is not likely to be introduced	-80% total points (at end)
Unknown	U
	9

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes)	6
Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0
Unknown	U
	0

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great	-60% total points (at end)

Lakes)	
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0
Unknown	U
	-10 %

- *It is well known that the* Cyprinella whipplei *is food for many larger animals including any gar, bass, sunfish, sturgeon, large chubs, kingfisher, heron species, and turtles (Mayden 2013). These fish and other species are common in many lakes and rivers of the Great Lakes basin (MDEQ 2008). However, this predation may be no different than for native minnow species of the Great Lakes. The predation may not prevent, improve, or lessen the establishment.*
- *There is a possibility that the* Cyprinella whipplei *could be susceptible to the Viral Hemorrhagic Septicemia Virus Strain, Genotype IVb that occurs in some Michigan fish (Faisal et al. 2012), and this could spread or subtract from its numbers during establishment though this has not been researched.*

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9
Frequent, moderate inocula	6
Frequent, small inocula OR infrequent, large inocula	3
Infrequent, small or moderate inocula	0
Unknown	U
	U

- *The Steelcolor Shiner Minnow is motile in connecting streams (Trautman 1980).*
- *This species occurs in the Mississippi River; however, introduction events are prevented by electrical barriers between the Mississippi River and the Great Lakes. The size and frequency of inocula from other rivers near the Great Lakes basin is unknown.*

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0

Unknown	U
	3

- *It is uncertain in the literature as to how far north the native range for the Steelcolor Shiner always was (Gibbs 1963, Hubbs and Cooper 1936, Page and Burr 2011, Robins et al. 1991), since there was a phylogenetic revision after 1938. Data prior to this date cannot be certain as to whether it was one or another species of minnow. However, there is a pattern in the DNR range maps with* Cyprinella spiloptera *and* Cyprinella camura*, as well as* Cyprinella whipplei *of a northward movement in range border over time (Cucherousset and Olden 2011, Kulhanek et al. 2011).*
- *It is not known through research whether this spread is simply due to a fish's mobility or if it involves direct or indirect human activity (e.g., bait bucket dumping or global warming).*
- *A survey conducted by Fisher et al. (1998) in 1994 found that* Cyprinella whipplei *had expanded its range in Tippecanoe County, Indiana since the mid-1970's. A 1978 survey collected 2 specimens of* Cyprinella whipplei*, and the 1994 survey collected 16 specimens; however, the authors note that the historically low abundance of* Cyprinella whipplei *could be attributed to misidentification of this species during the 1978 survey (Fisher et al. 1998).*
- *Although historically present in Indiana,* Cyprinella whipplei *was first recorded in the Kankakee River drainage in 1990 (Simon 1992).*
- Cyprinella whipplei *is established in Oklahoma (Fuller and Nico 2015a).*

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
	1

- *According to United States DNR fish survey range maps, there has been a slow progression of this Steelcolor Shiner Minnow species and related species in the same genus northward.*
- *The letters NI ("regarded as native but possibly introduced") and IP ("possibly introduced") are used to indicate the areas where* Cyprinella whipplei *is considered a native and where is it considered a long-time invasive (Hocutt and Wiley 1986). These data are needed to distinguish whether this species has invaded successfully in the long-term or recent past or whether it is indigenous.*

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing the establishment and spread of this species)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)

Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent the establishment and/or spread of this species	0
Unknown	U
	0

- *Other than dams and locks in place for energy or other needs, there is no known measure established specifically to block the Steelcolor Shiner Minnow. However, there are currently some blockages in place that are being monitored to prevent other known invasive fish species (Sparks 2010, United States 109th Congress 2005).*

Establishment Potential Scorecard				
Points	**Probability for Establishment**	A. Total Points (pre-adjustment)		68
>100	High	**Adjustments**		
		B. Critical species	A*(1- 0%)	68
51-99	Moderate	C. Natural enemy	B*(1- 10%)	61.2
		Control measures	C*(1- 0%)	61.2
0-50	Low	**Potential for Establishment**		Moderate
# of questions answered as "unable to determine"	**Confidence Level**			
0-1	High	Total # of questions unknown		2
2-5	Moderate			
6-9	Low	Confidence Level		Moderate
>9	Very low			

Section C: Potential for Impact

IMPACT POTENTIAL RESULTS

Environmental: Unknown

Socio-Economic: Low

Beneficial: Low

Current research on the potential for environmental impacts to result from *Cyprinella whipplei* if introduced to the Great Lakes is inadequate to support proper assessment.

There is insufficient information available to determine whether *Cyprinella whipplei* poses a threat to other species or water quality. There are no reports on how it affects or interacts with other species. It is unknown whether this species alters the physical components of the ecosystem.

There is little or no evidence to support that *Cyprinella whipplei* has the potential for significant socio-economic impacts if introduced to the Great Lakes.

It has not been reported that *Cyprinella whipplei* poses a threat to human health or water quality. There is no evidence that this species negatively impacts infrastructure, economic sectors, recreational activities and associated tourism, or the aesthetic appeal of the areas it inhabits.

There is little or no evidence to support that *Cyprinella whipplei* has the potential for significant beneficial impacts if introduced to the Great Lakes.

It has not been indicated that *Cyprinella whipplei* can be used for the control of other organisms or improving water quality. There is no evidence to suggest that this species is commercially, recreationally, or medically valuable. It does not have significant positive ecological impacts.

POTENTIAL ENVIRONMENTAL IMPACT

NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1
Not significantly	0
Unknown	U √

- *Though the Steelcolor Shiner has been studied in terms of its phylogeny (Mayden 1989, Page and Burr 2011) and community relationships (Daulwater et al. 2008, Doll 2010, Felley 1983), but it has not been studied in terms of carrying toxins or pathogens.*
- *Some comparable studies have been done with the Viral Hemorrhagic Septicemia Virus strain, Genotype IVb that occurs in some Michigan fish (Faisal et al. 2012). This virus is known to infect similar species of minnow such as* Notropis atherinoides *(Emerald Shiner). However, a possible infection in the Steelcolor Shiner minnow could work to lower its established numbers as well as increase spread of the virus though no research has shown this.*
- *Another consideration in the invasion of a new minnow that has not been studied in the Steelcolor Shiner Minnow is its ability to carry and spread environmental toxins as a prey species though not create the toxins (Levengood and Schaeffer 2011, USEPA 1990).*

E2) Does it outcompete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1
Not significantly	0 √
Unknown	U

- *No specific studies have been done on populations of the Steelcolor Shiner Minnow invading an area and outcompeting a native species. However, several studies have been done on environmental factors affecting stream communities (Aadland and Kuitunen 2004, Daulwater et al. 2008, Doll 2010, Felley 1983, Knouft and Page 2011). These studies never demonstrated that the Steelcolor Shiner Minnow has any advantage over other stream fish and in fact can be delicate in certain situations.*
- *Studies involving the Steelcolor Shiner Minnow in its native habitat, in which it is prey for larger fish common in the Great Lakes basin, do not show an increase in these larger, sport/food fishes (Doll 2010).*

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in the food web)	6
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	1
Not significantly	0
Unknown	U √

- *No specific studies have been done on populations of the Steelcolor Shiner Minnow invading an area and significantly altering the predator-prey relationships in those waters. However, several studies have been done on environmental factors affecting stream communities (Aadland and Kuitunen 2004, Daulwater et al. 2008, Doll 2010, Felley 1983, Knouft and Page 2011). These studies often take into account the food web and the rise or decline of other populations. These studies and further descriptions of the Steelcolor Shiner's habits (Page and Burr 2011, Smith 2002, Trautman 1980) show it has a delicate prey-specific diet of microinvertebrates as well as being prey for larger fish such as gar, bass, sunfish, sturgeon, large chubs, kingfisher, heron species, and turtles. These relationships may be normal to any prey minnow currently in the Great Lakes basin and not have a great impact, though no definitive proof is available (Ross et al. 2001).*

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0
Unknown	U √

- *Specific studies have been done on the hybridization between the Steelcolor Shiner Minnow and other related species, specifically* Cyprinella spiloptera *which is present in most areas of the Great Lakes basin (Mayden pers. comm. 2013). The long-term results of this genetic blending is not known. After 1938 one species,* Notropis whipplii, *was renamed and two or more species became more specific and described by morphology and zoogeography including* Cyprinella whipplei *and* Cyprinella spiloptera *(Gibbs 1963, Hubbs and Cooper 1936, Schönhuth and Mayden 2010). It is possible that hybridization can increase the range of such a minnow yet it could work to decrease its actual numbers.*

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1
Not significantly	0
Unknown	U √

- *Though no study specific to the Steelcolor Shiner minnow was done to reveal that it has an effect on water quality, general knowledge about this fish as a minnow does not reveal any outstanding abilities. Its life cycle and habit generally mimic those of other native minnows to the Great Lakes basin (Hocutt and Wiley 1986, Hubbs and Cooper 1936, Trautman 1980).*
- *Some notable fish assemblage studies of cognate fish could reveal whether the Steelcolor Shiner Minnow has some affect that would permeate post-invasion (Knouft and Page 2011, Mueller and Pyron 2010, Pritchett and Pyron 2011, Taylor 2000).*

E6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1
Not significantly	0
Unknown	U √

- *Though no study specific to the Steelcolor Shiner Minnow was done to reveal that it alters the physical qualities of a water ecosystem, general knowledge about this fish as a minnow does not reveal any outstanding abilities. Its life cycle and habit generally mimic those of other native minnows to the Great Lakes basin (Hocutt and Wiley 1986, Hubbs and Cooper 1936, Trautman 1980).*
- *Some notable fish assemblage studies of cognate fish could reveal whether the Steelcolor Shiner Minnow has some affect that would permeate post-invasion (Knouft and Page 2011, Mueller and Pyron 2010, Pritchett and Pyron 2011, Taylor 2000).*

Environmental Impact Total	**0**

Total Unknowns (U)	**5**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	Low
1	0	
0	≥2	**<u>Unknown</u>**
1	≥1	

<u>POTENTIAL SOCIO-ECONOMIC IMPACT</u>

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1
Not significantly	0 √
Unknown	U

- *The Steelcolor Shiner Minnow, like many other fishes, can carry common parasites. Given the proximity of its normal range (Page and Burr 2011) it is very likely that these threats are already present. There is no study specific to the levels of these hazards in* Cyprinella whipplei *but comparable studies and the abundant presence of its closest relative,* Cyprinella spiloptera, *in the Great Lakes gives confidence to the low risk of danger (Mayden 1989, USDA APHIS 2008).*

S2) Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1
Not significantly	0 √
Unknown	U

- *Though no studies have been done on infrastructure damage of the Steelcolor Shiner Minnow, it is highly unlikely that it will do any more damage than minnows currently in the Great Lakes basin, especially its close phylogenetic relative,* Cyprinella spiloptera.

- *No evidence has been shown that the Steelcolor Shiner Minnow does any damage to physical structures or recreation areas in its native ranges. This specific risk assessment rank is based on the absence of studies or reports on this specific topic.*

S3) Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0 √
Unknown	U

- *There is little published data on the steelcolor shiner minnow adversely affecting water quality (Neff and Killian 2003, Pritchett and Pyron 2011). This minnow prefers less turbid, moderately moving riverine environments and is regarded as generally less tolerant of varied habitats. In its native range, it is not reported to alter the environment in which it inhabits (Mueller and Pyron 2010, Page and Burr 2011).*

S4) Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

- *This minnow is not reported to be farmed or raised in aquaculture (INDNR 2013). This is most likely due to its more delicate nature and preference for the pools of moderate running clear rivers (Hocutt and Wiley 1986, Mayden 2013).*
- *There is no report of the steelcolor Shiner Minnow in its ranges negatively affecting any economic, sport, recreational or agricultural setting. It does not outcompete other native minnows nor increase predator numbers who feed upon it (Daulwater et al. 2008, Doll 2010, Hocutt and Wiley 1986).*

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

- *In the studies related to river habitat changes and community relationships, no report of the Steelcolor Shiner Minnow having adverse effects on recreational tourism, fishing, water usage, etc. It is generally regarded as more delicate when living in the presence of a biodiversity and not present in harsher environments (Doll 2010, Mayden 2013).*

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

- *In the studies related to river habitat changes and community relationships, no report of the Steelcolor Shiner Minnow having adverse effects on aesthetic value or natural value. It is generally regarded as more delicate when living in the presence of a biodiversity and not present in harsher environments (Doll 2010, Mayden 2013).*

Socio-Economic Impact Total	**0**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**<u>Low</u>**
1	0	
0	≥2	Unknown
1	≥1	

<u>POTENTIAL BENEFICIAL EFFECT</u>

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular effect. An "Unknown" response is appropriate if the potential for a particular effect might be inferred but has not been explicitly reported or if there is an unresolved debate about a particular effect.

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1
Not significantly	0 √
Unknown	U

- *There are no reports of the steelcolor shiner having any control ability over aquatic vegetation or harmful organisms. It is itself a predator of macroinvertebrates (Page and Burr 2011). This would affect a larger food web, (either beneficial or invasive) but no studies have been done on this effect.*

B2) Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?

Yes, it is economically important to at least one of these industries	6
Yes, but its economic contribution is small	1
Not significantly	0 √
Unknown	U

- *Though there seems an obvious possibility of the Steelcolor Shiner being used as bait or reared in aquaculture for ponds or bait, in over 50 years of literature, it is never listed as being farmed or even attempted to be farmed (Hubbs et al. 1933, MIDNR 2013, Willoughby 1965, Yoder and Division 1950). This may be due to its more sensitive nature and its need for clean river flow and crevice spawning needs (Mayden 2013, Pflieger 1965, Taylor 2000).*

B3) Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local communities and/or tourism	6
It is sometimes employed recreationally, but adds little value to local communities or tourism	1
Not significantly	0
Unknown	U √

- *The fact that minnows serve as prey for larger sport and food fish is an important aspect of any minnow species. However, the effect of the Steelcolor Shiner Minnow in the Great Lakes basin has not been studied. It could be assumed that the effect of the more delicate steelcolor shiner minnow would have similar affects as the local, related minnows that are indigenous to this area.*

B4) Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR It is potentially important to medicine or research and is currently being or scheduled to be studied	1
Not significantly	0 √
Unknown	U

- *No research exists demonstrating that the Steelcolor Shiner Minnow has medicinal or alternate research value. There is some research on related minnows such as the Bluntnose Shiner and the Emerald Shiner in terms of the effects of invasives, toxicity levels, and the VHS virus (Faisal et al. 2012, Levengood and Schaffer 2011, Winton et al. 2007).*

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1

Not significantly	0 √
Unknown	U

- *Though toxins can be found in the bodies of several related minnow species (Levengood and Schaeffer 2011), there is not research specific to the Steelcolor Shiner Minnow. There is little published data on this minnow removing significant levels from the water or adversely affecting the predators who feed on the minnows.*

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1
Not significantly	0 √
Unknown	U

Beneficial Effect Total	**0**
Total Unknowns (U)	**1**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**Low**
1	0	
0	≥2	Unknown
1	≥1	

Scientific Name: *Hypophthalmichthys molitrix*
Valenciennes in Cuvier and Valenciennes, 1844

Common Name: Silver Carp

Synonyms:

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: Moderate

Hitchhiking/fouling: Unlikely

Unauthorized intentional release: Moderate

Stocking/planting/escape from recreational culture: Unlikely

Escape from commercial culture: Moderate

Transoceanic shipping: Low

Hypophthalmichthys molitrix **has a moderate probability of introduction to the Great Lakes (Confidence level: High).**

Potential pathway(s) of introduction: Dispersal, Unauthorized Intentional Release, Escape from Commercial Culture, Transoceanic Shipping

Asian carp introduced to the Mississippi River basin via escape from aquaculture, identified as having relatively high probability of invasion if introduced to the Great Lakes (Herborg et al. 2007, Kolar and Lodge 2002, Kolar et al. 2005, Mandrak and Cudmore 2005, USEPA 2008); listed as having extensive invasion history (GISD 2006b). Potential pathway of introduction: inter-basin connections. Currently, large populations of *Hypophthalmichthys molitrix* (Silver Carp) are already established in nearby waters connected to the Great Lakes basin including the Illinois river and the Chicago Area Waterway System (Baerwaldt et al. 2013).

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100 √
No, this species does not occur near waters connected to the Great Lakes basin and/or is not mobile or able to be transported by wind or water.	0

Unknown	U

- *Large populations of Silver Carp are established in the middle and lower segments of the Illinois River, the upper Illinois River (Waterway), and the Chicago Area Waterway System (CAWS) (Baerwaldt et al. 2013).*

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75 √
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25
Unknown	U

- *Large populations of Silver Carp are established in the middle and lower segments of the Illinois River, the upper Illinois River (Waterway), and the Chicago Area Waterway System (CAWS) (Baerwaldt et al. 2013).*
- *The United States Army Corps of Engineers (USACE) constructed a set of three electrical barriers, the first of which opened in 2002, on the Chicago Sanitary and Shipping Canal (CSSC) to prevent the spread of aquatic invasive species between the Great Lakes and Mississippi River basins (Baerwaldt et al. 2013).*
- *The closest location to Lake Michigan at which Silver Carp has been collected was in the Des Plaines River (river mile 290.2) at the confluence with the CSSC, north of Joliet, IL and downstream of the electric barriers (USGS 2012).*
- *While not indicative of live fish, environmental DNA (eDNA) of Silver Carp was been found in water samples collected above the electric barriers (i.e., closer to Lake Michigan) in 2012 from Lake Calumet, the Little Calumet River, the North Shore Channel, and the Chicago River (USACE 2012).*
- *Additional eDNA of silver carp has been found in Maumee Bay, Lake Erie (OH and MI waters) (MIDNR 2012).*
- *It remains unclear if any ponds could connect with the Lake Michigan watershed during flooding events, but the presence of Silver Carp in near by ponds does provide a source of individuals in close proximity for illegal movement (Cudmore et al. 2012).*

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0 √
Unknown	U

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a) Is this species sold at aquarium/pet/garden stores ("brick & mortar" or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100 √
No, this species this species is rarely/never sold.	0
Unknown	U

- *Silver Carp are sometimes available in live food fish markets in several major United States and Canadian cities. Silver Carp has been placed on a watch list of freshwater food fish species in Ontario that had not yet been reported by importers or wholesalers, or been observed in retail markets, but that might become popular as a live food fish in the future. (Kolar et al. 2005).*
- *Also see (Mandrak and Cudmore 2005) regarding sale in Canada*
  The potential for purposeful, human-mediated releases of Bigheaded Carps into the Great Lakes basin does exist. Humans have illegally released freshwater fishes for sport opportunities (Crossman and Cudmore 1999a, Bradford et al. 2008) or spiritual/ethical reasons (Crossman and Cudmore 1999b, Severinghaus and Chi 1999, Shiu and Stokes 2008). This behavior of illegally releasing nonnative fishes into the aquatic environment is difficult to characterize and quantify (Bradford et al. 2008). For this reason, the rosk of intential release has not been quatified, but should be noted as a potential source of introduction of Bigheaded Carps into the Great Lakes basin (Cudmore et al. 2012).
- *The live baitfish pathway is a potential entry pathway for the arrival of small Bigheaded Carps into the Great Lakes (Cudmore et al. 2012).*
- *Feeder fishes (typically Goldfish (*Carassius auratus*) shipped into the Great Lakes basin could be contaminated with Bigheaded Carps if they originated from fish farms in the Mississippi River basin. Fathead Minnows found in the bait industry in Michigan are known to originate from culture in Arkansas, Minnesota, North Dakota, and South Dakota.. However, the volume of such movement and the extent of contamination, if any, is unknown. Based on a subsample of live fish import records for 2006-2007, Fathead Minnows (likely rosy reds) imported for the aquarium trade originated primarily from Missouri and secondarily from North (Cudmore et al. 2012).*
- *It is currently illegal to possess or sell live Asian carps in Ontario; however, despite this legislation, Bighead Carp and Grass Carp were documented in shipments for import into Ontario. Eight entry records were recorded from January 2010 to August 2011 that listed Grass (9.8 mt) and Bighead (16.8 mt) Carps as species descriptions. All of the shipments originated from Arkansas (Cudmore et al. 2012).*

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5 √
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1
Unknown	U

- *Most states prohibit the use of carp as baitfish with Michigan and Ontario specifically prohibiting the use of Asian Carp (Cudmore et al. 2012).*
- *Prohibition against using carp for bait in MN, WI, IN, MI, NY, Ontario, Quebec; whitelisted bait species in other GL states (Cudmore et al. 2012).*
- *Results from Drake's (2011) study of the baitfish industry and AIS in Ontario suggest that the entry route of Bigheaded Carps into the Great Lakes basin through the baitfish pathway will be largely dependent on the*

specific baitfish activity within each jurisdiction such as: characteristics of harvest activity in relation to bigheaded carp source populations; angler use, movement patterns, release rates; and, the yearly volume and spatial distribution of angling events within and outside of the Great Lakes basin (Cudmore et al. 2012).

- *A survey of bait shops in the Chicago area was conducted in 2010 to determine if Bigheaded Carp was present in bait tanks, it used both visual and eDNA surveillance methods (Jerde et al. 2012). No Bighead or Silver Carps were observed or detected by visual inspections or eDNA analysis (Cudmore et al. 2012).*
- *The possession and sale of live Asian carps within the province of Quebec is currently legal, but prohibition regulations are posted for the public (Cudmore et al. 2012).*
- *There is also no international trade of Bigheaded Carps identified with the Lake Superior watershed. Lake Michigan was ranked low for human-mediated release; higher than for Lake Superior given the proximity of established populations as a source of available individuals. Lakes Huron and Ontario are associated with a low risk, taking into consideration the lack of movement of bait and trade from Bigheaded carp areas and these lakes. However, these lakes are exposed to stronger fisheries from American anglers compared to Lake Superior, and Lake Ontario is also the location of live markets that could be involved in illegal trade. The risk of direct arrival to Lake Erie is also low, taking into consideration the presence of a higher number of anglers in lakes St. Clair and Erie, the frequent use of live bait in the area, and the potential for accidental release from illegal shipping of Bigheaded Carps coming from Windsor towards Toronto. Certainty associated with human-mediated releases varies by lake from low to moderate (Cudmore et al. 2012).*

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0 √
Unknown	U

- *Silver Carp are not currently raised or stocked as biological control agents to improve water quality in the United States, However, there is some interest within the aquaculture industry in potentially producing Silver Carp on a commercial scale in the future as part of Partitioned Aquaculture (Conover et al. 2007).*

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is <u>likely</u> to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces), this activity <u>may</u> occur within 20 km of the basin because of the species' popularity/value.	Score x 0.25 √
Unknown	U

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100 √
No, this species is not commercially cultured in or transported through the Great Lakes region.	0
Unknown	U

- *Silver carp are prohibited for United States import and interstate transport by the Lacey Act (USFWS 2006).*
- *Bigheaded carps, which are listed under the injurious wildlife provisions of the Lacey Act, cannot be legally imported into the United States or moved interstate live without a permit. Since 2005, the eight Great Lakes states have amended their rules and regulations to prohibit movement and/or possession of live Bigheaded Carps across their jurisdictions. Even with these regulations, enforcement could be improved, given that live Bighead Carp have been transported through United States (Cudmore et al. 2012).*
- *In Canada there is no federal legislation in place regarding import of aquatic species that may pose an invasion risk. The Ontario Ministry of Natural Resources (OMNR) has banned the live sale of Asian Carps through the Fish and Wildlife Conservation Act in 2004 and banned the live possession of Asian Carps through the Ontario Fishery Regulations in 2005 (Cudmore et al. 2012).*
- *Live silver carp are sometimes available in live food fish markets in several major United States and Canadian cities. Goodchild (1999) placed silver carp on a watch list of freshwater food fish species in Ontario that had not yet been reported by importers or wholesalers, or been observed in retail markets, but that might become popular as a live food fish in the future(Kolar et al. 2005).*

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5 √
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100 √
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains,	40

chain locker) while in its active or resting stage.	
No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0
Unknown	U

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5
Yes, but this species has neither been observed in ballast/fouling ships entering the Great Lakes nor in ports in direct trade with the Great Lakes.	Score x 0.1
No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0 √
Unknown	U

Vector Potential Scorecard				
Vector	**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind	**100**	x 0.75	**75**	Moderate
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.	**0**	x	**0**	Unlikely
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)	**100**	x 0.5	**50**	Moderate
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)	**0**	x 0.25	**0**	Unlikely
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)	**100**	x 0.5	**50**	Moderate
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling	**100**	x	**0**	Low
Total Unknowns (U) **0**		**Confidence Level**	High	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

ESTABLISHMENT POTENTIAL RESULTS

Status: Established in North America, but not the Great Lakes

***Hypophthalmichthys molitrix* has a moderate probability of establishment if introduced to the Great Lakes (Confidence level: High).**

Although Silver Carp has not been physically detected in the Great Lakes, environmental DNA (eDNA) has been found in water samples collected in several areas in 2012: above electric barriers from Lake Calumet, the Little Calumet River, the North Shore Channel, and the Chicago River (USACE 2012), as well as Maumee Bay, Lake Erie (MIDNR 2012).

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
	7

- *Silver carp are freshwater fish, preferring large river systems, lakes, or impoundments with flowing water, which they need to spawn. They can feed in temperatures as low as 2.5°C (36.5°F) and can withstand low levels of oxygen(PA Sea Grant 2013).*

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9
Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
	8

- *Overwinter mortality is correlated to length of winter and becomes more important with increasing latitude. It is not known to be an issue for Bigheaded Carps in the Mississippi River basin; Bigheaded Carp fingerlings have been collected from floodplain wetlands in spring in years when the wetlands were not connected to the river. Overwinter mortality may influence the northern limits of the native range of Bigheaded Carps, but has not been modelled specifically for these species in North America. Ecological niche modeling predicting the potential North American distribution of Bigheaded Carps indicated that they could survive well north of the Great Lakes basin (Herborg et al. 2007); therefore, overwinter mortality will likely not be a limiting factor in most years (Cudmore B. et al. 2012).*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
	5

- *The Silver Carp has unique, sponge-like and porous gill rakers capable of straining phytoplankton down to 4 lm in diameter (Robison and Buchanan 1988). Adults feed primarily on phytoplankton, but Silver Carp larvae feed on zooplankton (Chen et al. 2006).*

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3

Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	0
Unknown	U
	9

- *Silver Carp are thought to deplete plankton stocks for native larval fishes and mussels (Laird and Page 1996). They might be direct competitors for the adults of native species who feed on plankton, such as Paddle-fish (*Polyodon spatula*), Bigmouth Buffalo (*Ictiobus bubalus*) and the Gizzard Shad (*Dorosoma cepedianum) *(Chen et al. 2006).*

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
	6

- *Bigheaded Carps are known to spawn in rivers and it is believed that flood events are a primary spawning cue (Kolar et al. 2007). In its native range, Bighead Carp has a fecundity ranging from 280,000-1.1 million eggs (Kolar et al. 2007). In North America, fecundity ranged from 4,792-1.6 million eggs (Kipp et al. 2011). In its native range, Silver Carp has a fecundity ranging from 299,000-5.4 million eggs (Kolar et al. 2007). In North America, it has ranged from 26,650- 3.7 million eggs (Kipp et al. 2011).*

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
	0

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- *Ecological niche modeling predicting the potential North American distribution of Bigheaded Carps indicated that they could survive well north of the Great Lakes basin (Herborg et al. 2007); therefore, overwinter mortality will likely not be a limiting factor in most years (Cudmore et al. 2012).*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- *Ecological niche modeling predicting the potential North American distribution of Bigheaded Carps indicated that they could survive well north of the Great Lakes basin (Herborg et al. 2007); therefore, overwinter mortality will likely not be a limiting factor in most years (Cudmore et al. 2012).*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0
Unknown	U
	5

- *Recent studies have examined the suitability of Great Lakes tributaries for Bigheaded Carp spawning based on more detailed considerations of reproductive biology. Kocovsky et al. (2012) examined eight American tributaries in the central and western basins of Lake Erie. They concluded that the three larger tributaries were* *thermally and hydrologically suitable to support spawning of Bigheaded Carps, four tributaries were less suited, and that one was ill suited. Mandrak et al. (2011) conducted a similar analysis for the 25 Canadian tributaries of the Great Lakes. They concluded suitable spawning conditions were present in nine of 14 tributaries to Lake Superior with sufficient data; however, only one of the nine tributaries had a mean annual total degree-days exceeding 2,685. Therefore, Bigheaded Carps are unlikely to mature within Lake Superior tributaries, but may encounter sufficient growing degree-days to mature in some parts of Lake Superior such as near shore and bays. Mandrak et al. (2011) concluded suitable spawning conditions, including growing degree-days required for maturation, were present in 23 of 27 tributaries to Lake Huron, nine of 10 tributaries to Lake Erie, and 16 of 28 tributaries to Lake Ontario. Studies have not been conducted for United States tributaries in lakes Michigan, Huron, Superior, Ontario, nor the eastern basin of Lake Erie, but the analyses of Kocovsky et al. (2012) and Mandrak et al. (2011) suggest that access to tributaries with suitable thermal and hydrologic regimes in the Great Lakes should not limit spawning by Bigheaded Carps (Cudmore et al. 2012).*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0
Unknown	U
	9

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
	8

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Great Lakes and is not likely to be introduced	-80% total points (at end)
Unknown	U
	9

- *This species does not require another species for critical stages.*

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes)	6
Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0
Unknown	U
	0

- *Silver Carp will not be aided by the establishment of any other species.*

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0
Unknown	U
	0

- *Silver Carp are not found to have any predators or enemies.*

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9
Frequent, moderate inocula	6
Frequent, small inocula OR infrequent, large inocula	3
Infrequent, small or moderate inocula	0
Unknown	U
	2

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0

Unknown	U
	9

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
	9

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing the establishment and spread of this species)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent the establishment and/or spread of this species	0
Unknown	U
	-40%

- *Asian Carp management and control plans can be used for Silver Carp.*
- *Asian Carp Control Strategy Framework can be used for Silver Carp.*
- *Asian Carp Regional Coordinating Committee can be used for Silver Carp.*
- *Asian Carp Monitoring and Rapid Response Plan can be used for Silver Carp.*
- *eDNA monitoring can be used for Silver Carp.*

Establishment Potential Scorecard			
Points	**Probability for Establishment**	A. Total Points (pre-adjustment)	102
>100	High	**Adjustments**	

		B. Critical species	A*(1- 0%)	102
51-99	Moderate	C. Natural enemy	B*(1- 0%)	102
		Control measures	C*(1- 40%)	61.2
0-50	Low	**Potential for Establishment**		Moderate
# of questions answered as "unable to determine"	**Confidence Level**			
0-1	High	Total # of questions unknown		0
2-5	Moderate			
6-9	Low	Confidence Level		High
>9	Very low			

Section C: Potential for Impact

<u>IMPACT POTENTIAL RESULTS</u>

Environmental: High

Socio-Economic: High

Beneficial: Moderate

***Hypophthalmichthys molitrix* has a high potential environmental impact in the Great Lakes.**

Silver Carp is an efficient filter feeder which competes with virtually every fish species that which forages on planktonic organisms during their early life history stages (Chick and Pegg 2001). Interspecific competition for resources is known to cause pronounced and frequent declines in the physical condition of native fish when plankton resources are limited. Ultimately, declines in body condition may decrease potential fitness and the long-term sustainability of native fishes (Irons et al. 2007). Meso- and microcosm studies (Domaizon and Devaux 1999b, Spataru and Gophen 1985, Starling 1993) provide supporting evidence that high consumption caused by the superior filter efficiency and large size (>35 kg) of Silver Carp, may disproportionately deplete plankton and/or alter the assemblage of zooplankton communities, consequently modifying food web structure (Irons et al. 2007, Pongruktham et al. 2010).
These fish can excrete their own weight in 10 days (Herodek et al. 1989). This sediment enrichment has an ultimate negative effect on water quality. Studies (Lieberman 1996, Starling 1993) demonstrated that high biomass of Silver Carp causes increases in inorganic nitrogen and phosphorus levels. Decreases in zooplankton populations resulted in consequent increases in chlorophyll a and turbidity.

The Silver Carp has been known to be a carrier of the Asian tapeworm after the pathogen was found in Silver Carp stocks in the former U.S.S.R. and Philippines (Kolar et al. 2007). The Asian tapeworm, a cestode capable of being transferred to other fishes of several different orders, has minimal effects on Silver Carp but can cause severe or even lethal intestinal damage to novel hosts (Kolar et al. 2005). In addition, Kolar et al. (2005) points out that this parasite has been found in several species of native North American fishes, including several endangered species.

***Hypophthalmichthys molitrix* has a high potential socio-economic impact in the Great Lakes.**

One of the behaviors observed in Silver Carp is responsible for significant negative impact on the recreational/tourism sector. Silver Carp regularly jump out of the water, particularly in response to outboard motors. These leaps cause collisions between boaters and fish and have been the source of numerous reports of injuries to human beings and damage to boats and boating equipment. Silver Carp also causes property damage including broken radios, depth finders, fishing equipment, and antennae (USFWS 2006). Jumping of Silver Carp (at least 10 feet out of the water) can result in serious injuries to boaters and it is probable that collisions between boaters and jumping Silver Carp will eventually result in human fatalities (Hoff 2004).

Silver Carp are known to harbor several disease-causing agents that pose health risks to humans. These pathogen have been mostly found in carp from different parts of Iran. They include *Listeria monocytogenes* (found in market and fish farm samples), *Clostridium botulinum* (found in 1.1% of fresh and smoked samples from the Mazandaran Province), the toxigenic fungi *Aspergillus flavus, Alternaria, Penicillium,* and *Fusarium* (found from silver carp and from pond water in which they were raised) (USFWS 2006). Furthermore, Silver Carp can be considered a potential carrier for *Salmonella* (*S. typhimumium*) (USFWS 2006).

These fish compete with native species that are important as sport and food species and whose decline could result in a negative economic impact on recreational angling and other industries that benefit from sport fishing, such as tourism (Kolar et al. 2005).

***Hypophthalmichthys molitrix* has the potential for moderate beneficial effects if introduced to the Great Lakes.**

Silver Carp are of high commercial importance in many parts of the world. According to Kolar (2005) more Silver Carp are produced than any other species of freshwater fish in the world, especially in China where it continues to grow in importance. In the US, commercial harvest of silver carp is increasing in parts of the Mississippi River Basin (Conover et al. 2007). The combined annual commercial harvest of Bighead and Silver Carps from the Mississippi and Illinois rivers within Illinois increased from less than 600 kg per year between 1988 and 1992 to in excess of 50,000 kg per year since 1997 (Chick and Pegg 2001). A consumer market for Asian Carp species is being investigated in the United States and fishing tournaments for Silver carp are starting to develop in the US.

Silver Carp are frequently subjects of biomanipulation research with the purpose of cleaning wastewaters and eutrophic lakes (Domaizon and Devaux 1999b, Henderson 1978, Spataru and Gophen 1985, Starling 1993). These filter feeding fish were utilized in Henderson's (1978) field tests in order to determine their capabilities in controlling excessive plankton blooms and converting nutrients into usable proteins. Henderson found that the presence of the fish did affect plankton removal and stimulate nutrient uptake. Nonetheless, more recent studies (Domaizon and Devaux 1999, Spataru and Gophen 1985, Starling 1993) had contradictory results; therefore the ability of Silver Carp to control water quality remains unknown.

Silver Carp's ability as a biological agent for controlling cyanobacteria blooms has also been widely debated. Although cyanobacteria produce toxins that can be noxious to animals and humans, Silver Carp possess natural defenses against these microcystins and are known to consume blue-green algae (Xie et al. 2004). Miura (1990) has attributed phytoplankton community shifts from blue-green algae domination towards green algae to grazing by silver carp (Kolar et al. 2005). On the other hand, Kucklentz (1985) found that blue-green algae, as well as total phytoplankton, increased rather than decreased after stocking Silver Carp (Kolar et al. 2005).

POTENTIAL ENVIRONMENTAL IMPACT

NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6 √
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1
Not significantly	0
Unknown	U

- *The silver Carp has been known to be a carrier of the Asian tapeworm after the pathogen was found in silver carp stocks in the former U.S.S.R. and Philippines (Kolar et al. 2007). The Asian tapeworm, a cestode capable of being transferred to other fishes of several different orders, has minimal effects on Silver Carp but can cause severe or even lethal intestinal damage to novel hosts (Kolar et al. 2005). In addition, Kolar et al. (2005) points out that this parasite has been found in several species of native North American fishes, including several endangered species.*

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1 √
Not significantly	0
Unknown	U

- *Silver Carp is a filter feeder. Being efficient consumers of phytoplankton, cyanobacteria, and zooplankton, the Silver Carp competes with virtually every fish species in the Mississippi River basin that forage on planktonic organisms (Chick and Pegg 2001). Furthermore, Silver Carp has been found to have an overlapping diet with two native Great Lakes filter-feeder species, the Gizzard Shad and the Bigmouth Buffalo (Sampson et al. 2009). The interspecific competition for resources resulting from this overlap is known to cause pronounced and frequent declines in the physical condition of these native fish if plankton resources are limited. Ultimately, declines in body condition may decrease potential fitness and the long-term sustainability of Gizzard Shad, Bigmouth Buffalo, and other native riverine fishes (Irons et al. 2007).*

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in the food web)	6 √
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	1
Not significantly	0
Unknown	U

- *Mesocosmic and microcosmic studies carried out in lakes in France, Brazil, and Israel (Domaizon and Devaux 1999b, Spataru and Gophen 1985, Starling 1993) provide supporting evidence that high consumption caused by the superior filter efficiency and large size (>35 kg) of Silver Carp, may disproportionately deplete plankton and/or alter the assemblage of zooplankton communities, consequently modifying food web structure (Irons et al. 2007, Pongruktham et al. 2010).*

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0 √
Unknown	U

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1 √
Not significantly	0
Unknown	U

- *The possibility of Silver Carp as a bio-tool for improving water quality (by filtering phytoplankton and detritus) is still disputed. Some of the most recent studies (Lieberman 1996, Starling 1993) demonstrated that high biomass of Silver Carp causes increases in inorganic nitrogen and phosphorus levels. Decreases in zooplankton populations were shown, which in turn cause increases in microphytoplankton and consequently increases in chlorophyll a and turbidity. The increase in nutrient levels can be explained by the amount of feces excreted by Silver Carp. These fish can excrete their own weight in 10 days (Herodek et al. 1989). This sediment enrichment has an ultimate negative effect on water quality.*

E6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1 √
Not significantly	0
Unknown	U

- *The highly efficient filtering abilities of Silver Carp, aided by the complexity of their relationship with phytoplankton and zooplankton communities, leads to changes in phytoplankton assemblage via the impact on herbivorous zooplankton (Domaizon and Devaux 1999b).*

Environmental Impact Total	**15**
Total Unknowns (U)	**0**

Scoring		
Score	# U	**Impact**
>5	Any	**<u>High</u>**
2-5	Any	Moderate
0	0-1	Low
1	0	Low
0	≥2	Unknown
1	≥1	Unknown

<u>POTENTIAL SOCIO-ECONOMIC IMPACT</u>

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1 √
Not significantly	0
Unknown	U

- *Silver Carp is known to harbor several disease-causing agents that pose health risks to humans. These pathogen have been mostly found in carp from different parts of Iran. They include* Listeria monocytogenes *(found in market and fish farm samples),* Clostridium botulinum *(found in 1.1% of fresh and smoked samples from the Mazandaran Province), the toxigenic fungi* Aspergillus flavus*,* Alternaria*,* Penicillium*, and* Fusarium *(found from silver carp and from pond water in which they were raised) (USFWS 2006). Furthermore, silver carp can be considered a potential carrier for* Salmonella *(*S. typhimumium*) (USFWS 2006).*
- *It should also be noted that the jumping of Silver Carp (at least 10 feet out of the water) can result in serious injuries to boaters and it is probable that collisions between boaters and jumping Silver Carp will eventually result in human fatalities (Hoff 2004).*

S2) Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1
Not significantly	0 √
Unknown	U

S3) Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0 √
Unknown	U

S4) Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0
Unknown	U √

- *While the increased competition and habitat disruption may impact commercially-fished species, there has never been any formal analysis of this impact.*

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6 √
Yes, but negative consequences have been small	1
Not significantly	0
Unknown	U

- *Silver Carp regularly jump out of the water, particularly in response to outboard motors. These leaps cause collisions between boaters and fish and have been the source of numerous reports of injuries to human beings and damage to boats and boating equipment. Reported injuries include cuts from fins, black eyes, broken bones, neck and back injuries, and concussions. Silver Carp also causes property damage including broken radios, depth finders, fishing equipment, and antennae (USFWS 2006). Additionally, when a Silver Carp lands in a boat, it often leaves slime, scales, feces, and blood for boaters to contend with (Kolar et al. 2005). These fish also compete with native species that are important as sport and food species and whose decline could result in a negative economic impact on recreational angling and other industries that benefit from sport fishing, such as tourism (Kolar et al. 2005).*

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

Socio-Economic Impact Total	**7**
Total Unknowns (U)	**1**

Scoring		
Score	# U	**Impact**
>5	Any	**<u>High</u>**
2-5	Any	Moderate
0	0-1	Low
1	0	
0	≥2	Unknown
1	≥1	

<u>POTENTIAL BENEFICIAL EFFECT</u>

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular effect. An "Unknown" response is appropriate if the potential for a particular effect might be inferred but has not been explicitly reported or if there is an unresolved debate about a particular effect.

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1 √
Not significantly	0
Unknown	U

- *The ability if Silver Carp as a biological agent for controlling cyanobacteria blooms has been widely debated. Although cyanobacteria produce toxins that can be noxious to animals and humans, Silver Carp possess natural defenses against these microcystins and are known to consume blue-green algae (Xie et al. 2004). Miura (1990) has attributed phytoplankton community shifts from blue-green algae domination towards green algae to grazing by Silver Carp (Kolar et al. 2005). On the other hand, Kucklentz (1985) found that blue-green algae, as well as total phytoplankton, increased rather than decreased after stocking Silver Carp (Kolar et al. 2005); therefore the use of Silver Carp to control blue-green algae is not fully understood and has been met with varied success (Kolar et al. 2005).*

B2) Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?

Yes, it is economically important to at least one of these industries	6
Yes, but its economic contribution is small	1 √
Not significantly	0
Unknown	U

- *Silver Carp are of high commercial importance in many parts of the world. According to Kolar (2005) more Silver Carp are produced than any other species of freshwater fish in the world, especially in China where it continues to grow in importance. In the US, commercial harvest of Silver Carp is increasing in parts of the Mississippi River basin (Conover et al. 2007). The combined annual commercial harvest of Bighead and Silver Carps from the Mississippi and Illinois rivers within Illinois increased from less than 600 kg per year between 1988 and 1992 to in excess of 50,000 kg per year since 1997 (Chick and Pegg 2001).*
- *A consumer market for Asian Carp species is being investigated in the US.*

B3) Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local communities and/or tourism	6
It is sometimes employed recreationally, but adds little value to local communities or tourism	1 √
Not significantly	0
Unknown	U

- *Fishing tournaments for Silver Carp are starting to develop in the US.*

B4) Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR It is potentially important to medicine or research and is currently being or scheduled to be studied	1 √

Not significantly	0
Unknown	U

- *Silver Carp are frequently subjects of biomanipulation research with the purpose of cleaning wastewaters and eutrophic lakes (Domaizon and Devaux 1999b, Henderson 1978, Spataru and Gophen 1985, Starling 1993).*

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1
Not significantly	0
Unknown	U √

- *The feeding habits of Silver Carp make this species capable of converting primary production into fish flesh without supplemental feeding. These filter feeding fish were utilized in Henderson's (1978) field tests in order to determine their capabilities in controlling excessive plankton blooms and converting nutrients into usable proteins. Henderson found that the presence of the fish did affect plankton removal and stimulate nutrient uptake. Nonetheless, more recent studies (Domaizon and Devaux 1999, Spataru and Gophen 1985, Starling 1993) had contradictory results; therefore the ability of Silver Carp to control water quality remains unknown.*

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1
Not significantly	0 √
Unknown	U

- *According to Opuszynski 1981 and Yashouv 1971, culturing Silver Carp with other species can be an efficient method of increasing fishery production. It has been reported that the presence of Silver Carp in polyculture improves growth of Common Carp and Tilapias because benthic fishes cause resuspension of organic matter (Kolar et al. 2005). However, these species are not native to the Great Lakes.*

Beneficial Effect Total	**4**
Total Unknowns (U)	**1**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	**Moderate**
0	0-1	Low
1	0	

0	≥2	Unknown
1	≥1	

Scientific Name: *Hypophthalmichthys nobilis*
Richardson, 1845

Common Name: Bighead Carp

Synonyms:

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: Moderate

Hitchhiking/fouling: Unlikely

Unauthorized intentional release: Moderate

Stocking/planting/escape from recreational culture: Low

Escape from commercial culture: Moderate

Transoceanic shipping: Low

***Hypophthalmichthys nobilis* has a moderate probability of introduction to the Great Lakes (Confidence level: High).**

Potential pathway(s) of introduction: Dispersal, Unauthorized Intentional Release, Escape from Commercial Culture, Transoceanic Shipping

Asian Carp introduced to the Mississippi River basin via escape from aquaculture, identified as having relatively high probability of invasion if introduced to the Great Lakes (Herborg et al. 2007, Kolar et al. 2005, Mandrak and Cudmore 2005, Rixon et al. 2005, USEPA 2008); listed as having extensive invasion history (GISD 2005c) and as invasive in the Baltic Sea (Leppäkoski and Olenin 2000). Potential pathway of introduction: inter-basin connections.

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100 √
No, this species does not occur near waters connected to the Great Lakes basin and/or is not mobile or able to be transported by wind or water.	0
Unknown	U

- *Three Bighead Carp adults were collected in Lake Erie between 1995 and 2000 (Baerwaldt et al. 2013), but they are not thought to represent an established population. The body condition of these individuals were healthy, but the individuals dissected, had reproductive organs that were not viable (Cudmore et al. 2012).*

- *Large populations of Bighead Carp are established in the middle and lower segments of the Illinois River, the upper Illinois River (Waterway), and the Chicago Area Waterway System (CAWS) (Baerwaldt et al. 2013).*

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75 √
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25
Unknown	U

- *Large populations of Bighead Carp are established in the middle and lower segments of the Illinois River, the upper Illinois River (Waterway), and the Chicago Area Waterway System (CAWS) (Baerwaldt et al. 2013).*
- *Bighead Carp individuals have also been collected in isolated Chicago lagoons (e.g., Schiller Park Pond, Columbus Park Lagoon, Garfield Park Lagoon, McKinley Park Lake, Flatfoot Lake) closer to Lake Michigan (Baerwaldt et al. 2013). In 2008, a Bighead Carp was found in Lincoln Park South Lagoon, which connects to Lake Michigan via a screened overflow drain; this pond was poisoned and drained in late 2008 (Willink 2009).*
- *Bighead Carp is found in ponds that could connect with the Lake Michigan watershed during flooding events, which provides a source of individuals in close proximity for illegal movement (Cudmore et al. 2012).*
- *The United States Army Corps of Engineers (USACE) constructed a set of three electrical barriers, the first of which opened in 2002, on the Chicago Sanitary and Shipping Canal to prevent the spread of aquatic invasive species between the Great Lakes and Mississippi River basins; only one live Bighead Carp has been found (Lake Calumet in 2010) in the waterway above the barrier (Baerwaldt et al. 2013). A dead individual was found on the shore of Lake George, Indiana (Baerwaldt et al. 2013).*
- *While not indicative of live fish, environmental DNA (eDNA) of Bighead Carp was been found in water samples collected above the electric barriers (i.e., closer to Lake Michigan) in 2012 from Lake Calumet (USACE 2012).*
- *There are no known Bigheaded Carps in or near the St. Lawrence River. Should they gain access to the St. Lawrence River, through ballast water or via natural dispersal, would have a direct route to Lake Ontario (Cudmore et al. 2012).*

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0 √
Unknown	U

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a) Is this species sold at aquarium/pet/garden stores ("brick & mortar" or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100 √
No, this species this species is rarely/never sold.	0
Unknown	U

- *The potential for purposeful, human-mediated releases of Bigheaded Carps into the Great Lakes basin does exist. Humans have illegally released freshwater fishes for sport opportunities (Crossman and Cudmore 1999a, Bradford et al. 2008) or spiritual/ethical reasons (Crossman and Cudmore 1999b, Severinghaus and Chi 1999, Shiu and Stokes 2008). This human behavior of illegally releasing nonnative fishes into the aquatic environment is difficult to characterize and quantify; therefore it is difficult to qualify the risk of intentional release, but it should be noted as a potential source of introduction for Bigheaded Carps into the Great Lakes basin (Cudmore et al. 2012).*
- *Being used as a live baitfish is a potential pathway for the arrival of small Bigheaded Carps into the Great Lakes (Cudmore et al. 2012).*
- *Feeder fishes (typically Goldfish (*Carassius auratus*) or "rosy reds", colour variant of Fathead Minnow (*Pimephales promelas*), shipped into the Great Lakes basin could be contaminated with Bigheaded Carps if they originated from fish farms in the Mississippi River basin. Fathead Minnows found in the bait industry in Michigan are known to originate from culture in Arkansas, Minnesota, North Dakota, and South. However, the volume of such movement and the extent of contamination remains unknown (Cudmore et al. 2012).*
- *It is currently illegal to possess or sell live Asian Carps in Ontario; however, despite this legislation, Bighead Carp and Grass Carp have been documented in shipments for import into Ontario (Cudmore et al. 2012).*

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5 √
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1
Unknown	U

- *Most states prohibit the use of carp as baitfish. Michigan and Ontario specifically prohibiting the use of Asian carps (Cudmore et al. 2012)*
- *There is prohibition against using carp for bait in MN, WI, IN, MI, NY, Ontario, Quebec (Cudmore et al. 2012)*
- *Drake (2011) conducted a study of the baitfish industry and AIS in Ontario the results suggested that the entry route of Bigheaded Carps into the Great Lakes basin through the baitfish pathway will be largely dependent on the specifics of baitfish activity within each jurisdiction such as: characteristics of harvest activity in relation to bigheaded carp source populations; angler use, movement patterns, release rates; and, the yearly volume and spatial distribution of angling events within and outside of the Great Lakes basin (Cudmore et al. 2012)*

- *A survey of bait shops in the Chicago area was conducted in 2010 to determine presence of bigheaded carps in bait tanks using both visual and eDNA surveillance methods (Jerde et al. 2012). No Bighead or Silver Carps were observed or detected by visual inspections or eDNA analysis (Cudmore et al. 2012).*
- *The possession and sale of live Asian carps within the province of Quebec is currently legal, but there are prohibition regulations for the public (Cudmore et al. 2012).*
- *There is also no international trade of Bigheaded Carps identified with the Lake Superior watershed. Lake Michigan was ranked low for human-mediated release; higher than for Lake Superior given the proximity of established populations as a source of available individuals. Lakes Huron and Ontario are associated with a low risk, taking into consideration the lack of movement of bait and trade from Bigheaded Carp. However, these lakes are exposed to stronger fisheries from American anglers compared to Lake Superior, and Lake Ontario is also the location of live markets that could be involved in illegal trade. The risk of direct arrival to Lake Erie is also low, taking into consideration the presence of a higher number of anglers in lakes St. Clair and Erie, the frequent use of live bait in the area, and the potential for accidental release from illegal shipping of bigheaded carps coming from Windsor towards Toronto. (Cudmore et al. 2012).*

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100 √
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0
Unknown	U

- *There are many ponds and artificial lakes in the Chicago metropolitan area. They are commonly stocked for fishing with Channel Catfish (*Ictalurus punctatus*). Channel Catfish are often purchased from southern fish farmers, where it is possible for the stock to be contaminated with small Bighead Carp (Cudmore et al. 2012).*
- *Fewer catfish farmers are raising Bighead Carp since the species was listed as 'injurious' under the Injurious Wildlife provisions of the Lacey Act. The Act prohibits interstate transport of live Bighead Carp (Cudmore et al. 2012).*

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is likely to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces), this activity may occur within 20 km of the basin because of the species' popularity/value.	Score x 0.25 √
Unknown	U

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100 √
No, this species is not commercially cultured in or transported through the Great Lakes region.	0
Unknown	U

- *Bigheaded Carps are listed under the injurious wildlife provisions of the Lacey Act and cannot be legally imported into the United States or moved interstate live without a permit. Since 2005, the eight Great Lakes states have amended their rules and regulations to prohibit movement and/or possession of live Bigheaded Carps across their jurisdictions. Even with these regulations fishes were seized in Canada in 2010-2011 (Cudmore et al. 2012).*
- *In Canada, there is no federal legislation in place regarding import of aquatic species that may pose an invasion risk. The Ontario Ministry of Natural Resources (OMNR) has banned the live sale of Asian Carps through the Fish and Wildlife Conservation Act in 2004 and banned the live possession of Asian Carps through the Ontario Fishery Regulations in 2005 (Cudmore et al. 2012).*
- *Some illegal shipment attempts into Ontario have been stopped by Canadian enforcement officers. In November 2010, there was a seizure at the Bluewater Bridge, Sarnia of 1,136 kg of Bighead Carp and 727 kg of Grass Carp after officers from both Canada Border Services Agency and OMNR inspected incoming shipments of live and fresh fishes. In March 2011, a fish importer was fined $50,000 for transporting live Bighead Carp (nearly 2,500 kg) from the United States across the Windsor- Detroit border. A few days later, an Indiana company was caught bringing live Bighead Carp (2,727 kg) into Canada and was fined $20,000. All fishes originated in Arkansas and were headed to live fish markets in the Toronto area (Cudmore et al. 2012).*

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5 √
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100 √
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80

No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40
No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0
Unknown	U

- *Unlike the ballast water in freighters that originate outside of the Great Lakes, ballast water in freighters that remain in the St. Lawrence River basin are not treated for AIS in any way. If Bigheaded Carps were to become established first in the St. Lawrence River, the freighter movement may facilitate the arrival of the species into the Great Lakes basin (Cudmore et al. 2012).*

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5
Yes, but this species has neither been observed in ballast/fouling ships entering the Great Lakes nor in ports in direct trade with the Great Lakes.	Score x 0.1
No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0 √
Unknown	U

Vector	Raw Points Scored	Proximity Multiplier	Total Points Scored	Probability of Introduction
Dispersal: Natural dispersal through waterbody connections or wind	**100**	x 0.75	**75**	Moderate
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.	**0**	x	**0**	Unlikely
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)	**100**	x 0.5	**50**	Moderate
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)	**100**	x 0.25	**25**	Low
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)	**100**	x 0.5	**50**	Moderate
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling	**100**	x	**0**	Low
Total Unknowns (U)	**0**	**Confidence Level**	High	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

ESTABLISHMENT POTENTIAL RESULTS

Status: **Established in North America, but not the Great Lakes**

Hypophthalmichthys nobilis **has a moderate probability of establishment if introduced to the Great Lakes (Confidence level: High).**

Asian Carp introduced to the Mississippi River basin via escape from aquaculture are identified as having relatively high probability of invasion if introduced to the Great Lakes (Herborg et al. 2007, Kolar et al. 2005, Mandrak and Cudmore 2005, Rixon et al. 2005, USEPA 2008); they are listed as having extensive invasion history (GISD 2005c) and as invasive in the Baltic Sea (Leppäkoski and Olenin 2000). Potential pathway of introduction: inter-basin connections.

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
	7

- *Bighead Carp have been able to establish themselves in a wide range of environments with a wide range of temperatures and lower salinity levels.*

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9
Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
	8

- *Bighead Carp are known to be able to tolerate a wide variety of temperature but their locations in Asia suggest their ability to withstand the Great Lake waters during the winter period.*
- *Overwinter mortality is correlated to length of winter and becomes more important with increasing latitudes. It is not known to be an issue for Bigheaded Carps in the Mississippi River basin; Bigheaded Carp fingerlings are collected from floodplain wetlands in the spring in years when those wetlands were not connected to the river. Overwinter mortality may influence the northern limits of the native range of Bigheaded Carps, but this has not been modelled for these species in North America. Ecological niche modeling in their native range predicts the potential for North American distribution of Bigheaded Carps and indicated that they could survive well north of the Great Lakes basin (Herborg et al. 2007); therefore, overwinter mortality would likely not be a limiting factor in most years (Cudmore B. et al. 2012).*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
	5

- *Bighead Carp are bottom feeders feeding mostly on zooplankton and often algae.*

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	0
Unknown	U
	9

- *Bighead Carp are expected to outcompete for food source in native species and could affect the prey of top predators in the Great Lakes.*

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
	5

- *The fecundity of Bigheaded Carp seems comparable to other species in the same taxonomic group.*
- *Bigheaded carps are known to spawn in rivers and it is believed that a flood event is the primary spawning cue (Kolar et al. 2007). In its native range, Bighead Carp has a fecundity ranging from 280,000-1.1 million eggs*

(Kolar et al. 2007). In North America, fecundity ranged from 4,792-1.6 million eggs (Kipp et al. 2011). In its native range, Silver Carp has a fecundity ranging from 299,000-5.4 million eggs (Kolar et al. 2007). In North America, it has ranged from 26,650- 3.7 million eggs (Kipp et al. 2011).

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
	0

- *Bighead Carp need large, turbulent rivers and higher temperatures to spawn. The eggs float for 40-60 hours before hatching (Chen et al 2007). Only some rivers emptying into the Great Lakes are sufficient of this characteristic and at only parts of the year.*

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- *Bighead carp's native regions are quite compatible to many regions in the United States and have already been found in areas surrounding the Great Lakes basin.*
- *Ecological niche modeling has predicted the potential for North American distribution of Bigheaded Carps and has indicated that they could survive well north of the Great Lakes basin (Herborg et al. 2007); therefore, overwinter mortality will likely not be a limiting factor (Cudmore B. et al. 2012).*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- *Ecological niche modeling has predicted the potential for North American distribution of Bigheaded Carps and has indicated that they could survive well north of the Great Lakes basin (Herborg et al. 2007); therefore, overwinter mortality will likely not be a limiting factor (Cudmore B. et al. 2012).*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0
Unknown	U
	5

- *The habitats needed for reproduction are more commonly found in rivers than in lakes. Bighead Carp need large, turbulent rivers and higher temperatures to spawn. The eggs float for 40-60 hours before hatching. Only some rivers emptying into the Great Lakes are sufficient of this characteristic and at only parts of the year.*
- *Two recent studies examined the suitability of Great Lakes tributaries for Bigheaded Carp spawning based on detailed considerations of reproductive biology. Kocovsky et al. (2012) examined eight American tributaries in the central and western basins of Lake Erie. They concluded that the three larger tributaries were thermally and hydrologically suitable to support spawning of Bigheaded Carps, four tributaries were less suited, and that one was ill suited. Mandrak et al. (2011) conducted a similar analysis for the 25 Canadian tributaries of the Great Lakes. They concluded suitable spawning conditions were present in nine of 14 tributaries to Lake Superior with sufficient data; however, only one of the nine tributaries had a mean annual total degree-days exceeding 2,685. Therefore, Bigheaded Carps are unlikely to mature within Lake Superior tributaries, but may encounter sufficient growing degree-days to mature in some parts of Lake Superior such as near shore areas and bays. Mandrak et al. (2011) concluded suitable spawning conditions, including growing degree-days required for maturation, were present in 23 of 27 tributaries to Lake Huron, nine of 10 tributaries to Lake Erie, and 16 of 28 tributaries to Lake Ontario. Similar studies have not been conducted for United States tributaries in lakes Michigan, Huron, Superior, Ontario, nor the eastern basin of Lake Erie, but the analyses of Kocovsky et al. (2012) and Mandrak et al. (2011) suggest that access to tributaries with suitable thermal and hydrologic regimes in the Great Lakes should not limit spawning by bigheaded carps (Cudmore B. et al. 2012).*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment	9

for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0
Unknown	U
	9

- *This species would be able to adapt to the effects of climate change and would allow for longer periods of reproduction.*

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
	8

- *It would be highly likely for the Bighead Carp to find an appropriate food source but the amount they eat might not be sufficiently found in the Great Lakes.*

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in	0

the Great Lakes but is likely to be introduced	
Yes, but the critical species (or one that may provide a similar function) is not present in the Great Lakes and is not likely to be introduced	-80% total points (at end)
Unknown	U
	9

- *This species does not require another species for critical stages.*

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes)	6
Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0
Unknown	U
	0

- *Bighead Carp will not be aided by the establishment of any other species.*

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0

Unknown	U
	0

- *Bighead Carp are not found to have any predators or enemies.*

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9
Frequent, moderate inocula	6
Frequent, small inocula OR infrequent, large inocula	3
Infrequent, small or moderate inocula	0
Unknown	U
	1

- *There are control measures to try and stop the introduction of bighead into the Great Lakes.*

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
	9

- *Bighead Carp have established in Europe and the Mississippi River.*

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3

Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
	9

- *Bighead Carp were able to establish themselves rapidly once introduced into habitats with the right conditions.*

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing the establishment and spread of this species)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent the establishment and/or spread of this species	0
Unknown	U
	-40%

- *Asian Carp management and control plans can be used for Bigheaded Carp.*
- *Asian Carp Control Strategy Framework can be used for Bigheaded Carp.*
- *Asian Carp Regional Coordinating Committee can be used for Bigheaded Carp.*
- *Asian Carp Monitoring and Rapid Response Plan can be used for Bigheaded Carp.*
- *eDNA monitoring can be used for Bigheaded Carp.*

Establishment Potential Scorecard				
Points	**Probability for Establishment**	A. Total Points (pre-adjustment)		100
>100	High	**Adjustments**		
		B. Critical species	A*(1- 0%)	100
51-99	Moderate	C. Natural enemy	B*(1- 0%)	100
		Control measures	C*(1- 40%)	60
0-50	Low	**Potential for Establishment**		Moderate
# of questions answered as "unable to determine"	**Confidence Level**			
0-1	High	Total # of questions unknown		0
2-5	Moderate			
6-9	Low			High

>9	Very low	Confidence Level	

Section C: Potential for Impact

IMPACT POTENTIAL RESULTS

Environmental: High

Socio-Economic: High

Beneficial: Moderate

Hypophthalmichthys nobilis **has a high potential environmental impact in the Great Lakes.**

Bighead Carp is a powerful filter-feeder with a wide food spectrum that grows fast and reproduces quickly (Xie and Chen 2001), which makes this species a strong competitor. Within its native China, Bighead Carp are considered invasive and are associated with declines in native planktivorous fishes when translocated outside their natural range (Li and Xie 2002). Xie and Chen found that stocking of bighead carp into the plateau lakes of China had disastrous effects on endemic fishes, especially filter-feeding, endemic Barbless Carp (*Cyprinus pellegrini*). The catch of barbless carp, that once represented 50% of yield of total fishes caught, declined to 20% in the 1960s, to 10% in the early 1970s, and plummeted to <1% in the 1980s.

The species also poses a threat to the ecology of the Mississippi River Basin and connecting aquatic ecosystems. These fish are capable of significantly reducing zooplankton abundance, which adversely affects all fish in their early life stages when their diets are strictly planktonic (Chick and Pegg 2001, Xie and Chen 2001). Furthermore, Bighead Carp compete with fish that are filter-feeders as adults, such as paddlefish. Several studies have showed that when zooplankton is limited, bighead carp has a competitive advantage over paddlefish, negatively affecting the relative growth of the latter (Schrank et al. 2003, Schrank and Guy 2002).

Furthermore, Bighead Carp can host two pathogens that have the potential of affecting and native fish species. One of these parasites, the gill-damaging *Lernaea cyprinacea*, known as anchorworm, was found in Channel Catfish being cultured with Bighead Carp (Goodwin 1999). This parasite is also known to affect salmonids and eels. Anchorworm occurs worldwide, is known from 40 cyprinid species, and completes its life history on a single host (Hoole et al. 2001). Bighead Carp is also known to be host of *Bothriocephalus acheilognathi*, known as the Asian Carp tapeworm. This cestode parasite, introduced into United States waters from grass carp, erodes mucus membranes and intestinal tissues, often leading to death of the host (Humpback Chub Ad Hoc Advisory Committee 2003). Yet, these adverse effects are minimal on Bighead Carp (Kolar et al. 2005). The Asian Carp tapeworm is known to have infected native fishes of concern in five states: Arizona, Colorado, Nevada, New Mexico, and Utah. As the introduced range of Bighead and Silver carps grows in United States waters, a number of native fishes, particularly, but not limited to, cyprinids, percids, and centrarchids, will probably become hosts of the Asian carp tapeworm (Kolar et al. 2005).

Hypophthalmichthys nobilis **has a high potential socio-economic impact in the Great Lakes.**

The spread of this species adversely affects commercial fishery in parts of the Mississippi River Basin (Maher 2005). Bighead Carp has become a substantial portion of commercial catch, significantly outnumbering the catch of native species sought after commercially in several waters of the Midwest (Conover et al. 2007, Kolar et al. 2005). Commercial fishers on the Illinois River reported a 124% increase in the harvest of Bighead and Silver Carps (reported together) and a 35% decrease in buffalo harvest during 2002. In the lower Missouri River, between 2002 and 2004, more than twice as many Hypophthalmichthys spp. were caught than all other commercial species combined. Furthermore, the average weight of individual *Hypophthalmichthys* spp. was estimated to be at least double that of the individual commercial species caught (Kolar et al. 2005). Unless economically viable markets develop, the establishment of large self-sustaining populations of Bighead Carp in the United States may compromise commercial fishing.

The diet of this species overlaps with that of planktivorous species (fish and invertebrates) and to some extent with that of the young of virtually all native fishes. If food resources become limiting, Bighead Carps may compete directly with these native species. The decline of native species that are important as sport and food species are bound to have a negative economic impact on recreational angling and other industries that benefit from sport fishing, such as tourism (Kolar et al. 2005).

***Hypophthalmichthys nobilis* has the potential for high beneficial effects if introduced to the Great Lakes.**

Bighead Carp is a popular food fish in its native China and several other countries, ranking fourth in 1999 in world aquaculture production (FAO 1999). Although not so popular in North America, commercial fisheries for bighead carp exist on the Mississippi, Missouri, and Illinois rivers and are sold from small specialty food markets to consumers of various Asian cultures in major North American cities (Conover et al. 2007, Kolar et al. 2005, Stone et al. 2000). Nonetheless, the market for live Bighead Carp in the United States is limited (the typical consumer will buy only enough fish for the current day's meal) and easily saturated. After Bighead Carp fry are produced by hatcheries and grown to market size by fish farmers, they are transported to live markets in Toronto, Chicago, New York, Boston, Montreal, and other cities (Conover et al. 2007).

Bighead Carp are frequently used in polyculture with other fish, such as Common Carp, various tilapias, Largemouth Bass, and Bigmouth Buffalo (Jennings 1988) to control zooplankton and phytoplankton populations. In the United States, Bighead Carp are cultured in ponds with channel catfish and sometimes with Grass Carp to control macrophytes (Conover et al. 2007).

Additionally, Bighead Carp can be an important source of revenue for catfish farmers during times of low catfish prices (Stone et al. 2000). Engle and Brown (1998) estimated that the net benefit of stocking Bighead Carp with catfish was substantially higher. Net benefits ranged from \$1,628 to \$2,743 annually from a 6-ha (15-acre) pond. Furthermore, there is evidence of Bighead Carp used as sport fish in Oklahoma. Relatively numerous sport fishing catches have been recorded downstream from a low-water dam in the Neosho River at Miami, Oklahoma (Jester et al. 1992).

The role of bighead carp as a biological control agent for plankton control and removal is largely debated. While Henderson (1978, 1983) suggested that both Bighead and Silver Carps would stimulate phytoplankton blooms that would result in removal of nutrients by phytoplankton, Opuszynski (1980) found that organic carbon, nitrogen, and total phosphorous increased in bottom sediments, despite the decrease in nitrogen, phosphorous, and dissolved. When those bottom sediments were disturbed by activities of other fishes, phytoplankton populations increased. Furthermore, Lieberman (1996) stocked Bighead and Silver Carps and found that total phosphorus and total inorganic nitrogen increased as a result. Yet, some studies have reported that Bighead Carp is able to improve water quality by continually removing plankton, especially blue-green algae. This stabilizes plankton and lessens the probability of die-offs in production ponds (Kolar et al. 2007, Schofield et al. 2005).

POTENTIAL ENVIRONMENTAL IMPACT

NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6 √
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1
Not significantly	0
Unknown	U

- *Bighead Carp is host to two pathogens that have the potential of affecting and native fish species. One of these parasites, the gill-damaging* Lernaea cyprinacea*, known as anchorworm, was found in channel catfish being cultured with Bighead Carp (Goodwin 1999). This parasite is also known to affect salmonids and eels. Anchorworm occurs worldwide, is known from 40 cyprinid species, and completes its life history on a single host (Hoole et al. 2001). Bighead Carp is also known to be host of* Bothriocephalus acheilognathi*, known as the Asian Carp Tapeworm. This cestode parasite, introduced into United States waters from Grass Carp, erodes mucus membranes and intestinal tissues, often leading to death of the host (Hoole et al. 2001, Humpback Chub Ad Hoc Advisory Committee 2003). Yet, these adverse effects are minimal on Bighead Carp (Kolar et al. 2005). The Asian Carp Tapeworm is known to have infected native fishes of concern in five states: Arizona, Colorado, Nevada, New Mexico, and Utah (Kolar et al. 2005). As the introduced range of Bighead and Silver Carps grows in United States waters, a number of native fishes, particularly, but not limited to, cyprinids, percids, and centrarchids, will probably become hosts of the Asian Carp Tapeworm (Kolar et al. 2005).*

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1 √
Not significantly	0
Unknown	U

- *Bighead Carp is a powerful filter-feeder with a wide food spectrum that grows fast and reproduces quickly (Xie and Chen 2001), which makes this species a strong competitor. Within its native China, Bighead Carp are considered invasive and are associated with declines in native planktivorous fishes when translocated outside their natural range (Li and Xie 2002). Xie and Chen (2001) found that stocking of Bighead Carp into the plateau lakes of China had disastrous effects on endemic fishes, especially filter-feeding, endemic Barbless*

- *Carp (*Cyprinus pellegrini*). The catch of BarblessCcarp, that once represented 50% of yield of total fishes caught, declined to 20% in the 1960s, to 10% in the early 1970s, and plummeted to <1% in the 1980s.*
- *Bighead Carp also pose a threat to the ecology of the Mississippi River basin and connecting aquatic ecosystems. These fish are capable of significantly reducing zooplankton abundance, which adversely affects all fish in their early life stages when their diets are strictly planktonic (Chick and Pegg 2001, Xie and Chen 2001). Furthermore, Bighead Carp compete with fish that are filter-feeders as adults, such as paddlefish. Several studies have showed that when zooplankton is limited, Bighead Carp has a competitive advantage over Paddlefish, negatively affecting the relative growth of the latter (Chick and Pegg 2001, Schrank et al. 2003, Schrank and Guy 2002).*

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in the food web)	6
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	1 √
Not significantly	0
Unknown	U

- *Bighead Carp have considerable effects on zooplankton communities. This fish are known to decrease the size of zooplankton within a species (Kim et al. 2003, Radke and Kahl 2002), possibly removing a species from the size category that will be consumed effectively by Paddlefish. It seems likely that* Hypophthalmichthys *have the potential to alter the food web in ways that could negatively affect fishes such as Paddlefish that feed on large crustacean zooplankton (Kolar et al. 2005).*

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0 √
Unknown	U

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected water quality to some extent, but the alterations and resulting adverse	1

effects have been limited or inconsistent (as compared with above statement)	
Not significantly	0
Unknown	U √

E6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1
Not significantly	0
Unknown	U √

Environmental Impact Total	**8**
Total Unknowns (U)	**2**

Scoring		
Score	# U	**Impact**
>5	Any	**<u>High</u>**
2-5	Any	Moderate
0	0-1	Low
1	0	
0	≥2	Unknown
1	≥1	

<u>POTENTIAL SOCIO-ECONOMIC IMPACT</u>

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6

Yes, but negative consequences have not been widespread, long lasting, or severe	1
Not significantly	0 √
Unknown	U

S2) Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1
Not significantly	0 √
Unknown	U

S3) Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0 √
Unknown	U

S4) Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6 √
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0
Unknown	U

- *The spread of this species adversely affects commercial fishery in parts of the Mississippi River basin (Maher 2005). Bighead Carp has become a substantial portion of commercial catch, significantly outnumbering the catch of native species sought after commercially in several waters of the Midwest (Conover et al. 2007, Kolar et al. 2005). Commercial fishers on the Illinois River reported a 124% increase in the harvest of Bighead and Silver Carps (reported together) and a 35% decrease in Buffalo harvest during 2002 (Conover et al. 2007). In the lower Missouri River, between 2002 and 2004, more than twice as many* Hypophthalmichthys *were caught than all other commercial species combined. Furthermore, the average weight of individual* Hypophthalmichthys *was estimated to be at least double that of the individual commercial species caught (Kolar et al. 2005). Unless economically viable markets develop, the establishment of large self-sustaining populations of Bighead Carp in the United States may compromise commercial fishing (Conover et al. 2007).*

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6 √
Yes, but negative consequences have been small	1
Not significantly	0

Unknown	U

- *The diet of this species overlaps with that of planktivorous species (fish and invertebrates) and to some extent with that of the young of virtually all native fishes. If food resources become limiting, Bighead Carps may compete directly with these native species. The decline of native species that are important as sport and food species are bound to have a negative economic impact on recreational angling and other industries that benefit from sport fishing, such as tourism (Kolar et al. 2005).*

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

Socio-Economic Impact Total	**12**
Total Unknowns (U)	**0**

Scoring		
Score	# U	**Impact**
>5	Any	**<u>High</u>**
2-5	Any	Moderate
0	0-1	Low
1	0	
0	≥2	Unknown
1	≥1	

POTENTIAL BENEFICIAL EFFECT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular effect. An "Unknown" response is appropriate if the potential for a particular effect might be inferred but has not been explicitly reported or if there is an unresolved debate about a particular effect.

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1 √
Not significantly	0

Unknown	U

- *The role of Bighead Carp as a biological control agent for plankton control and removal is largely debated. While Henderson (1978, 1983) suggested that both Bighead and Silver carps would stimulate phytoplankton blooms that would result in removal of nutrients by phytoplankton, Opuszynski (1980) found that organic carbon, nitrogen, and total phosphorous increased in bottom sediments, despite the decrease in nitrogen, phosphorous, and dissolved. When those bottom sediments were disturbed by activities of other fishes, phytoplankton populations increased. Furthermore, Lieberman (1996) stocked Bighead and Silver carps and found that total phosphorus and total inorganic nitrogen increased as a result.*

B2) Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?

Yes, it is economically important to at least one of these industries	6
Yes, but its economic contribution is small	1 √
Not significantly	0
Unknown	U

- *Bighead Carp is a popular food fish in its native China and several other countries, ranking fourth in 1999 in world aquaculture production (FAO 1999). Although not so popular, North American commercial fisheries for Bighead Carp exist on the Mississippi, Missouri, and Illinois rivers and are sold from small specialty food markets to consumers of various Asian cultures in major North American cities (Conover et al. 2007, Kolar et al. 2005, Stone et al. 2000). Nonetheless, the market for live Bighead Carp in the United States is limited (the typical consumer will buy only enough fish for the current day's meal) and easily saturated (Stone et al. 2000). After Bighead Carp fry are produced by hatcheries and grown to market size by fish farmers, they are transported to live markets in Toronto, Chicago, New York, Boston, Montreal, and other cities (Conover et al. 2007).*
- *Furthermore, Bighead Carp are frequently used in polyculture with other fish, such as Common Carp, various tilapias, Largemouth Bass, and Bigmouth Buffalo (Jennings 1988) to control zooplankton and phytoplankton populations. In the United States, Bighead Carp are cultured in ponds with Channel Catfish and sometimes with Grass Carp to control macrophytes (Conover et al. 2007).*
- *Additionally, bighead carp can be an important source of revenue for catfish farmers during times of low catfish prices (Stone et al. 2000). Engle and Brown (1998) estimated that the net benefit of stocking Bighead Carp with catfish was substantially higher. Net benefits ranged from $1,628 to $2,743 annually from a 6-ha (15-acre) pond.*

B3) Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local communities and/or tourism	6
It is sometimes employed recreationally, but adds little value to local communities or tourism	1
Not significantly	0 √
Unknown	U

- *There is evidence of Bighead Carp used as sport fish in Oklahoma. Relatively numerous sport fishing catches have been recorded downstream from a low-water dam in the Neosho River at Miami, Oklahoma (Jester et al. 1992).*

B4) Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR It is potentially important to medicine or research and is currently being or scheduled to be studied	1
Not significantly	0 √
Unknown	U

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1
Not significantly	0
Unknown	U √

- *The effects of Bighead Carp on water quality in culture ponds is highly debated due to conflicting results from various studies (Kolar et al. 2007, Stickney 1996). Yet, some studies have reported that Bighead Carp is able to improve water quality by continually removing plankton, especially blue-green algae. This stabilizes plankton and lessens the probability of die-offs in production ponds (Kolar et al. 2007, Schofield et al. 2005).*

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1
Not significantly	0 √
Unknown	U

Beneficial Effect Total	**2**
Total Unknowns (U)	**1**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	**Moderate**
0	0-1	Low
1	0	

0	≥2	Unknown
1	≥1	

Scientific Name: *Ictalurus furcatus*
Valenciennes in Cuvier and Valenciennes, 1840

Common Name: Blue Catfish, White Cat, White Fulton, Fulton, Humpback Blue, Forktail Cat, Blue Channel Catfish

Synonyms:

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: Low

Hitchhiking/fouling: Unlikely

Unauthorized intentional release: Low

Stocking/planting/escape from recreational culture: High

Escape from commercial culture: Unlikely

Transoceanic shipping: Unlikely

***Ictalurus furcatus* has a High probability of introduction to the Great Lakes (Confidence level: High).**

Potential pathway(s) of introduction: Escape from recreational culture, dispersal, unauthorized intentional release

Blue Catfish can migrate up to several hundred kilometers.The closest population to the Great Lakes basin is likely a stocked population documented in 1981 in Indian Lake, Ohio (Logan County), less than 20 km from the Lake Erie watershed (USGS 2012). However, this water body drains into the Ohio River and then into the Mississippi River, with no direct connection to the Great Lakes. Likewise, the sites of Minnesotan introductions (Lake St. Croix and Lake Peppin) also drain into the Mississippi River (USGS 2012). Blue Catfish is stocked for catch and keep at Litchfield Catfish Acres, Michigan, an artificial unconnected pond near the St. Joseph River (http://catfishacresphotos.webs.com/).

As a result of *I. furcatus* growing to exceptionally large sizes, it has been widely introduced as a food and sport fish and now occurs in 29 states throughout the Mississippi basin as well as the Atlantic, Pacific, and Gulf coastal slopes (Graham et al. 1999, Fuller and Neilson 2015b). Blue Catfish are often found in fish markets (Graham et al. 1999).

Other reasons for nonindigenous occurrences include intentional stocking or unintentional flooding of private waterbodies (Bonvechio et al. 2012, Guier et al. 1984, Mettee et al. 1996).

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100 √
No, this species does not occur near waters connected to the Great Lakes basin and/or is not mobile or able to be transported by wind or water.	0
Unknown	U

- Ictalurus furcatus *is endemic to the Mississippi, Missouri, and Ohio River basins of the central and southern United States and inhabits Gulf Coast streams from Alabama south into Mexico, but it has been recently introduced to many northern states (Graham et al. 1999, Padhi 2011).*
- Ictalurus furcatus *has been introduced to Alabama, Arizona, Arkansas, California, Colorado, Florida, Idaho, Maryland, Georgia, New Jersey, New Mexico, Minnesota, North Carolina, Ohio, Oklahoma Oregon, South Carolina, Virginia and Washington (Tuckey and Fabrizio 2011).*

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25 √
Unknown	U

- Ictalurus furcatus *is endemic to the Mississippi, Missouri, and Ohio River basins of the central and southern United States and inhabits Gulf Coast streams from Alabama south into Mexico, but it has been recently introduced to many northern states (Graham et al. 1999, Padhi 2011).*
- Ictalurus furcatus *has been introduced to Alabama, Arizona, Arkansas, California, Colorado, Florida, Idaho, Maryland, Georgia, New Jersey, New Mexico, Minnesota, North Carolina, Ohio, Oklahoma Oregon, South Carolina, Virginia and Washington (Tuckey and Fabrizio 2011).*
- *The closest population to the Great Lakes basin is likely a stocked population documented in 1981 in Indian Lake, OH (Logan County), less than 20 km from the Lake Erie watershed (USGS 2012); however, this water body drains into the Ohio River and then into the Mississippi River, with no direct connection to the Great Lakes. Likewise, the sites of Minnesotan introductions (Lake St. Croix and Lake Peppin) also drain into the Mississippi River (USGS 2012).*
- *Blue Catfish is stocked for catch and keep at Litchfield Catfish Acres, Michigan, an artificial unconnected pond near the St. Joseph River (http://catfishacresphotos.webs.com/).*

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by	100

other organisms entering the Great Lakes basin.	
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0 √
Unknown	U

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1
Unknown	U

<u>POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE</u>

3a) Is this species sold at aquarium/pet/garden stores ("brick & mortar" or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100 √
No, this species this species is rarely/never sold.	0
Unknown	U

- *As a result of* I. furcatus *growing to exceptionally large sizes, it has been widely introduced as a food and sport fish and now occurs in 29 states throughout the Mississippi basin as well as the Atlantic, Pacific, and Gulf coastal slopes (Graham et al. 1999, Fuller and Neilson 2015b).*
- *Blue Catfish is stocked for catch and keep at Litchfield Catfish Acres, Michigan, an artificial unconnected pond near the St. Joseph River (http://catfishacresphotos.webs.com/).*

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1 √
Unknown	U

- *Blue Catfish is stocked for catch and keep at Litchfield Catfish Acres, Michigan, an artificial unconnected pond near the St. Joseph River (http://catfishacresphotos.webs.com/).*

<u>POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE</u>

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100 √
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0
Unknown	U

- *Other reasons for nonindigenous occurrences of Blue Catfish include intentional stocking or unintentional flooding of private waterbodies (Bonvechio et al. 2012, Guier et al. 1984, Mettee et al. 1996).*
- *Blue Catfish is stocked for catch and keep at Litchfield Catfish Acres, Michigan, an artificial unconnected pond near the St. Joseph River (http://catfishacresphotos.webs.com/).*

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1 √
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is likely to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces), this activity may occur within 20 km of the basin because of the species' popularity/value.	Score x 0.25
Unknown	U

- *Blue Catfish is stocked for catch and keep at Litchfield Catfish Acres, Michigan, an artificial unconnected pond near the St. Joseph River (http://catfishacresphotos.webs.com/).*

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100
No, this species is not commercially cultured in or transported through the Great Lakes region.	0 √
Unknown	U

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25

This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40
No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0 √
Unknown	U

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5
Yes, but this species has neither been observed in ballast/fouling ships entering the Great Lakes nor in ports in direct trade with the Great Lakes.	Score x 0.1
No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0
Unknown	U

Vector Potential Scorecard				
Vector	**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind	**100**	x 0.25	**25**	Low
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.	**0**	x	**0**	Low

Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)	**100**	x 0.1	**10**	Low
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)	**100**	x 1	**100**	High
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)	**0**	x	**0**	Low
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling	**0**	x	**0**	Low
Total Unknowns (U)	**0**	**Confidence Level**	High	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

ESTABLISHMENT POTENTIAL RESULTS

Status: Established in North America, but not the Great Lakes

***Ictalurus furcatus* has a moderate probability of establishment if introduced to the Great Lakes (Confidence level: High).**

Ictalurus furcatus are found in many regions with continental climate similar to the Great Lakes. For example, found in Missouri River near Bismarck, North Dakota (Fuller and Neilson 2015b), which is at a latitude of 46°N. This region experiences harsh winters and hot summers- similar to the Great Lakes. Literature shows no mention of pollution, but this species inhabits the lower Mississippi and the Chesapeake Bay watershed, both of which include polluted conditions. Areas where *Ictalurus furcatus* are found have similar temperatures and salinities to the Great Lakes. *I. furcatus* inhabits large rivers and major tributaries associated with swift chutes and flowing waters around deep pools, as well as oxbow lakes and reservoirs (Bonvechio et al. 2012, Boschung and Mayden 2004, Jenkins and Burkhead 1994, Ross 2001).

This species is a dietary generalist that would likely find adequate food in the Great Lakes. Males guard eggs and fry (Graham et al. 1999) giving this species an advantage over other native fish that do not guard young.

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
	7

- I. furcatus *spawns in late spring to early summer at water temperatures of 21–25°C (Sublette et al. 1990) and have a faster growth rate during summer (at 20–28°C) (Grant and Robinette 1992, Padhi 2011).*
- I. furcatus *is migratory; it moves toward warmer waters during winter and to cooler waters during summer (Graham et al.1999).*
- I. furcatus *can tolerate salinities up to 15 ppt (Christmas and Waller 1973, Dennison et al. 1993, Hio et al. 2012, Perry 1968, Ross 2001).*
- I. furcatus *has 87% survival in "low DO" treatment (experiment 2) with DO of 1.41 ppm (Torrans et al. 2012).*
- *In fish farms in Mississippi Delta,* I. furcatus *had 95% survival after winter with low temperature of 5.1°C (Bosworth 2012).*
- I. furcatus *is found in Missouri River near Bismarck, ND (Fuller and Neilson 2015b), which is at a latitude of 46°N. While water temperatures are not available for this location, the harsh winters in this region make it likely* I. furcatus *can survive low temperatures.*

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9
Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
	6

- *In fish farms in the Mississippi Delta,* I. furcatus *had 95% survival after winter with low temperature of 5.1°C (Bosworth 2012).*
- I. furcatus *is found in Missouri River near Bismarck, ND (Fuller and Neilson 2015b), which is at a latitude of 46°N. While water temperatures are not available for this location, the harsh winters in this region make it likely* I. furcatus *can survive low temperatures.*
- I. furcatus *is migratory; it moves toward warmer waters during winter (Graham et al. 1999).*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
	5

Blue Catfish are highly omnivorous, utilizing more than 30 types of prey. A study done by Eggleton and Schramm (2004) found that collectively across all habitats, Blue Catfish diets were composed of 47% fishes (more than 15 identifiable species), 15% molluscs, 12% chironomids and oligochaetes, 7% detritus/plant matter, 6% decapods, 6% scavenging, 1% terrestrial arthropods. Scavenged items were typically fishes and fish scales, but also included small mammals, birds, and turtles (Eggleton and Schramm 2004).

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	0
Unknown	U
	9

- I. furcatus *is a large fish, reaching 40-50 kg (Graham et al. 1999).*
- *In studies of the James and Rappahannock rivers* I. furcatus *is estimated to make up 75% of the total fish biomass; associated with decline in native white catfish* I. catus *(Schloesser et al. 2011, Tuckey and Fabrizio 2011).*
- *Commercial landings in the Maryland and Virginia have increased from 9.5-17 metric tons in 2003-2005 to more than 72.5 metric tons in 2008 (Schloesser et al. 2011).*

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
	0

- I. furcatus *has a relative fecundity from 900 to 1,350 eggs/kg of body weight (Graham et al. 1999).*
- *Relative fecundity (eggs per kg body weight) of other siluroid species is as follows (Legendre et al. 1996):*
    - Silurus glunis*: 10,000-25,000*
    - Guleichthys feliceps*: 50,000*
    - lctalurus punctutus*: 8,000*
    - Chtysichthys nigrodigitaius*: 15,000-18,000*
    - Hoplosternum littorale*: 45,000-75,000*
    - Clarias gariepinus*: 60,000-150,000*
    - Clarias macrocephalus*: 20,000-50,000*
    - Heterobranchus longifilis*: 30,000-120,000*
    - Pseudoplatystoma coruscans*: 120,000-130,000*

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
	6

- I. furcatus *males of guard the eggs and fry (Graham et al. 1999).*

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6

Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	6

- I. furcatus *is found in many regions with continental climate similar to the Great Lakes. For example, they are found in Missouri River near Bismarck, ND (Fuller and Neilson 2015b), which is at a latitude of 46°N. This region experiences harsh winters and hot summers.*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	6

- *This species inhabits the lower Mississippi and the Chesapeake Bay watershed, both of which include polluted conditions.*
- *This species inhabits water with a range of currents, from swift chutes to oxbow lakes and floodplain lakes.*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0
Unknown	U
	4

- I. furcatus *inhabits large rivers and major tributaries associated with swift chutes and flowing waters around deep pools, as well as oxbow lakes and reservoirs (Bonvechio et al. 2012, Boschung and Mayden 2004, Jenkins and Burkhead 1994, Ross 2001).*
- I. furcatus *inhabits river channels: higher flows and harder substrates (i.e., gravel, boulders, rock rip rap); and floodplain lakes - lower or no flows and softer substrates (i.e., silt, sand) (Eggleton and Schramm 2004).*
- *Blue Catfish prefer open waters of large reservoirs and main channels, backwaters, and embayments of large, flowing rivers where water is normally turbid and substrate varies from gravel-sand to silt-mud (Burr and Warren 1986). Many rivers and reservoirs with Blue Catfish populations have only mud or silt substrate. Blue Catfish prefer deep, swift channels and flowing pools (Jenkins and Burkhead 1994), and large specimens were*

often found in tailwaters below dams where currents were swift and substrates consist of sand, gravel, and rock (Mettee et al. 1996, Graham et al. 1999).
- *Blue Catfish seek protected areas behind rocks, root-wads, depressions, undercut stream banks, or other areas where the currents are minimal to deposit eggs (Graham et al. 1999).*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0
Unknown	U
	9

- I. furcatus *has a faster growth rate during summer (at 20–28°C) (Grant and Robinette 1992, Padhi 2011).*
- *This species tolerates moderate salinity.*

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
	9

- I. furcaturs *on floodplain lakes consumed mainly clupeid fishes, chironomids, oligochaetes, and detritus/plant matter (Eggleton and Schramm 2004).*
- *Blue Catfish are highly omnivorous, utilizing more than 30 types of prey. A study done by Eggleton and Schramm (2004) found that collectively across all habitats, Blue Catfish diets were composed of 47% fishes (more than 15 identifiable species), 15% molluscs, 12% chironomids and oligochaetes, 7% detritus/plant matter, 6% decapods, 6% scavenging, 1% terrestrial arthropods. Scavenged items were typically fishes and fish scales, but also included small mammals, birds, and turtles (Eggleton and Schramm 2004).*

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Great Lakes and is not likely to be introduced	-80% total points (at end)
Unknown	U
	9

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes)	6
Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0
Unknown	U
	0

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0
Unknown	U
	0

- *This species guards fry, and grows to a large size.*

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9
Frequent, moderate inocula	6
Frequent, small inocula OR infrequent, large inocula	3
Infrequent, small or moderate inocula	0
Unknown	U
	0

- *As the primary vector would be unauthorized introductions or recreational escape, the inocula size would depend on human activity in these areas. This is not well-quantified and given the few search results for online suppliers, likely small.*

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0

Unknown	U
	4

- I. furcatus *is endemic to the Mississippi, Missouri and Ohio River basins of the central and southern United States and occupies Gulf Coast streams from Alabama, south into Mexico, but has been recently introduced to many northern states (Graham et al. 1999, Padhi 2011).*
- I. furcatus *has been introduced to Alabama, Arizona, Arkansas, California, Colorado, Florida, Idaho, Maryland, Georgia, New Jersey, New Mexico, Minnesota, North Carolina, Ohio, Oklahoma Oregon, South Carolina, Virginia and Washington (Tuckey and Fabrizio 2011).*

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
	6

- I. furcatus *is migratory; they can travel several hundred km (Graham et al. 1999).*
- I. furcatus *has spread rapidly though the Chesapeake Bay watershed (Schloesser et al. 2011).*

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing the establishment and spread of this species)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent the establishment and/or spread of this species	0
Unknown	U
	0

Establishment Potential Scorecard			
Points	**Probability for**	A. Total Points (pre-adjustment)	86

	Establishment			
>100	High	Adjustments		
		B. Critical species	A*(1- 0%)	86
51-99	Moderate	C. Natural enemy	B*(1- 0%)	86
		Control measures	C*(1- 0%)	86
0-50	Low	**Potential for Establishment**		Moderate
# of questions answered as "unable to determine"	**Confidence Level**			
0-1	High	Total # of questions unknown		0
2-5	Moderate			
6-9	Low	Confidence Level		High
>9	Very low			

Section C: Potential for Impact

IMPACT POTENTIAL RESULTS

Environmental: Moderate

Socio-Economic: Low

Beneficial: High

***Ictalurus furcatus* has the potential for moderate environmental impact if introduced to the Great Lakes.**

Ictalurus furcatus may introduce high levels of PCBs and other contaminants into avian predators (Schloesser et al. 2011). Homer and Jennings (2011) found shifts in the gillnet catch of *Ameiurus catus* (L.) (White Catfish) to Blue Catfish in Lake Oconee, GA, and suggested that competition by introduced Blue Catfish and Flathead Catfish could drive declines in the abundance of native White Catfish (Bonvechio et al. 2012). In studies of the James and Rappahannock rivers they are estimated to make up 75% of the total fish biomass; associated with decline in native White Catfish *I. catus* (Schloesser et al. 2011, Tuckey and Fabrizio 2011). In the Chesapeake watershed, *Ictalurus furcatus* may prey on economically and ecologically important estuarine fishes such as juvenile American Shad, Atlantic Menhaden, and River Herring (Schloesser et al. 2011). *Ictalurus furcatus* hybridizes with threatened Yaqui Catfish *I. pricei* in Mexico (USFWS 1994, Fuller and Neilson 2015b).

There is little or no evidence to support that *Ictalurus furcatus* has the potential for significant socio-economic impacts if introduced to the Great Lakes.

Ictalurus furcatus accumulate mercury in tissue (Nichols et al. 2002); this leads to many consumption advisories for this species where they are found. There is no evidence that this species negatively impacts infrastructure, economic sectors, recreational activities and associated tourism, or the aesthetic appeal of the areas it inhabits.

Ictalurus furcatus has the potential for high beneficial impact if introduced to the Great Lakes.

California stocks Blue Catfish for Asiatic Clam control (Graham et al. 1999) but is not very effective. *Ictalurus furcatus* are sport and commercial fisheries in 14 states, most of which are in east-central and southeastern states within the middle and lower Mississippi River and Ohio River basins (Graham et al. 1999, Holley et al. 2009, Michaletz and Dillard 1999). They are unpopular with the aquaculture industry because of reported slow maturation rates, poor food conversion, and poor spawning success in captivity (Graham et al. 1999). About one-half of the states where Blue Catfish occur (15) consider the species recreationally important (Graham et al. 1999, Michaletz and Dillard 1999, Schloesser et al. 2011).

POTENTIAL ENVIRONMENTAL IMPACT

NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1
Not significantly	0
Unknown	U √

- I. furcatus *may introduce high levels of PCBs and other contaminants into avian predators (Schloesser et al. 2011).*

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1 √
Not significantly	0
Unknown	U

- *Homer and Jennings (2011) found shifts in the gillnet catch of* Ameiurus catus *(L.) (White Catfish) to Blue Catfish in Lake Oconee, GA, and suggested that competition by introduced Blue Catfish and Flathead Catfish could drive declines in the abundance of native White Catfish (Bonvechio et al. 2012).*
- *In studies of the James and Rappahannock rivers they are estimated to make up 75% of the total fish biomass; associated with decline in native White Catfish* I. catus *(Schloesser et al. 2011, Tuckey and Fabrizio 2011).*

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in the food web)	6
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	1
Not significantly	0
Unknown	U √

- *In the Chesapeake watershed, Blue Catfish may prey on economically and ecologically important estuarine fishes such as juvenile American Shad, Atlantic Menhaden and River Herring (Schloesser et al. 2011).*

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1 √
Not significantly	0
Unknown	U

- I. furcatus *hybridizes with threatened Yaqui Catfish* I. pricei *in Mexico (Fuller and Neilson 2015b, USFWS 1994).*

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1
Not significantly	0 √
Unknown	U

E6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem	6

AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1
Not significantly	0 √
Unknown	U

Environmental Impact Total	**2**
Total Unknowns (U)	**2**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	**Moderate**
0	0-1	Low
1	0	
0	≥2	Unknown
1	≥1	

POTENTIAL SOCIO-ECONOMIC IMPACT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1 √
Not significantly	0
Unknown	U

- I. furcatus *cccumulates mercury in it's tissues (Nichols et al. 2002).*
- *There are many consumption advisories for this species in place.*

S2) Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1

Not significantly	0 √
Unknown	U

S3) Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0 √
Unknown	U

S4) Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

Socio-Economic Impact Total	**1**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**Low**
1	0	
0	≥2	Unknown
1	≥1	

POTENTIAL BENEFICIAL EFFECT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular effect. An "Unknown" response is appropriate if the potential for a particular effect might be inferred but has not been explicitly reported or if there is an unresolved debate about a particular effect.

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1 √
Not significantly	0
Unknown	U

- *California stocks Blue Catfish for Asiatic clam control (Graham et al. 1999).*

B2) Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?

Yes, it is economically important to at least one of these industries	6 √
Yes, but its economic contribution is small	1
Not significantly	0
Unknown	U

- I. furcatus *is in sport and commercial fisheries in 14 states, most of which are in east-central and southeastern states within the middle and lower Mississippi River and Ohio River basins (Graham et al. 1999, Holley et al. 2009, Michaletz and Dillard 1999).*
- *This species is unpopular with the aquaculture industry because of reported slow maturation rates, poor food conversion, and poor spawning success in captivity (Graham et al. 1999).*

B3) Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local communities and/or tourism	6 √
It is sometimes employed recreationally, but adds little value to local communities or	1

tourism	
Not significantly	0
Unknown	U

- *About one-half of the states where Blue Catfish occur (15) consider the species recreationally important (Graham et al. 1999, Michaletz and Dillard 1999, Schloesser et al. 2011).*

B4) Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR It is potentially important to medicine or research and is currently being or scheduled to be studied	1 √
Not significantly	0
Unknown	U

- I. furcatus *is used in toxicity analyses, e.g., used as bioindicator of malathion exposure (Aker et al. 2008).*

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1
Not significantly	0 √
Unknown	U

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1
Not significantly	0 √
Unknown	U

Beneficial Effect Total	**14**
Total Unknowns (U)	**0**

Scoring		
Score	# U	**Impact**
>5	Any	**<u>High</u>**

2-5	Any	Moderate
0	0-1	Low
1	0	
0	≥2	Unknown
1	≥1	

Scientific Name: *Knipowitschia caucasica*
Berg 1916

Common Name: Caucasian Dwarf Goby

Synonyms:

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: Unlikely

Hitchhiking/fouling: Unlikely

Unauthorized intentional release: Unlikely

Stocking/planting/escape from recreational culture: Unlikely

Escape from commercial culture: Unlikely

Transoceanic shipping: Moderate

***Knipowitschia caucasica* has a moderate probability of introduction to the Great Lakes (Confidence level: High).**

Potential pathway(s) of introduction: Transoceanic Shipping (ballast water)

Knipowitschia caucasica does not occur near waters connected to the Great Lakes basin. This species is not known to hitchhike or foul. *Knipowitschia caucasica* is not stocked, commercially cultured, or sold in the Great Lakes region. It occurs in the Mediterranean Sea, which has shipping traffic that goes directly to the Great Lakes; however, there is insufficient information to determine if this species occurs in the Mediterranean ports that are in direct trade with the Great Lakes. Due to its euryhaline nature, *Knipowitschia caucasica* may be able to survive ballast water management practices.

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100
No, this species does not occur near waters connected to the Great Lakes basin and/or is not mobile or able to be transported by wind or water.	0 √
Unknown	U

- *There have been no reports of* K. caucasica *near or in waters connected to the Great Lakes; however, the species has been accidently introduced to other European bodies of water from its original source in the Ponto-Caspian region.* K. caucasica *has been identified in several bodies of water in Greece (Economidis and Miller*

1990, Kevrekidis et al. 1990, Daoulas et al. 1993, Kovačić and Pallaoro 2003, Leonardos et al. 2008), Hungary (Halasi-Kovács et al. 2011), and Turkey (Van Neer et al. 1999).

- Knipowitschia caucasica *has only been identified in European waters (Economidis and Miller 1990, Kevrekidis et al. 1990, Daoulas et al. 1993, Van Neer et al. 1999, Kovačić and Pallaoro 2003, Leonardos et al. 2008, Halasi-Kovács et al. 2011).*

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0 √
Unknown	U

- *Invasion of* K. caucasica *into Turkish lakes was attributed to involuntary introduction by man through fish stocking or recreational fishing (Van Neer et al. 1999).*
- Knipowitschia caucasica *larvae were found in aquatic vegetation hauls in Greek lakes (Daoulas et al. 1993).*
- *Eggs are usually found attached to the underside of small gravel, mollusk shells, or reeds (Baimov 1963).*
- *In Europe,* K. caucasica *have been found in fish stocks of common carp (Van Neer et al. 1999).*
- *However*, K. caucasica *has only been identified in European waters (Economidis and Miller 1990, Kevrekidis et al. 1990, Daoulas et al. 1993, Van Neer et al. 1999, Kovačić and Pallaoro 2003, Leonardos et al. 2008, Halasi-Kovács et al. 2011).*

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a) Is this species sold at aquarium/pet/garden stores ("brick & mortar" or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100
No, this species this species is rarely/never sold.	0 √
Unknown	U

- *Performing an online search of aquaria, catalogs, and biological supply companies (including Carolina Biological, Aquatic Biosystems, and Fisher-Scientific) did not yield any listings or information for* K. caucasica *or the common name (caucasian dwarf goby)*
- Knipowitschia caucasica *is listed on the IUCN Redlist of Threatened Species, although as a low concern species with no known major threats (Freyhof and Kottelat 2008c). With this in mind, it may be difficult to acquire these species for market sales.*

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0 √
Unknown	U

- *An online search did not yield any listings or information for* K. caucasica *or the common name (caucasian dwarf goby)*
- Knipowitschia caucasica *is listed on the IUCN Redlist of Threatened Species, although as a low concern species with no known major threats (Freyhof and Kottelat 2008c). With this in mind, it may be difficult to acquire these species for market sales.*
- *Moreover,* K. caucasica *has only been identified in European waters (Economidis and Miller 1990, Kevrekidis et al. 1990, Daoulas et al. 1993, Van Neer et al. 1999, Kovačić and Pallaoro 2003, Leonardos et al. 2008, Halasi-Kovács et al. 2011).*

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is <u>likely</u> to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces), this activity <u>may</u> occur within 20 km of the basin because of the species' popularity/value.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100
No, this species is not commercially cultured in or transported through the Great Lakes region.	0 √
Unknown	U

- *Although* K. caucasica *is not transported or sold commercially in the Great Lakes region according to an online search, there is potential for the species to accidentally enter the basin illegally or through ballast water. Van Neer et al. (1999) and Daoulas et al. (1993) argue that* K. caucasica *has been accidently introduced into some European waters by stocks of other fish or recreational fishing.*
- *However,* K. caucasica *has only been identified in European waters (Economidis and Miller 1990, Kevrekidis et al. 1990, Daoulas et al. 1993, Van Neer et al. 1999, Kovačić and Pallaoro 2003, Leonardos et al. 2008, Halasi-Kovács et al. 2011).*
- *Furthermore,* K. caucasica *is listed on the IUCN Redlist of Threatened Species, although as a low concern species with no known major threats (Freyhof and Kottelat 2008c). With this in mind, it may be difficult to acquire this species for market sales.*

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80 √
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40
No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0
Unknown	U

- *Due to its small size (30-40mm) (Kevrekidis et al. 1990),* K. caucasica *can be easily taken up by ballast water systems.*
- Knipowitschia caucasica *has been found in other fish stocks, which has contributed to their introduction in Turkish and Greek water bodies (Van Neer et al. 1999). In addition, they have shown the ability to develop freshwater populations in European riverine and lake systems (Halasi-Kovács et al. 2011).*
- Knipowitschia caucasica *has wide ecological tolerances. They are a euryhaline species and can survive in both hypersaline and fresh water, allowing them to easy survive introduction to the Great Lakes from a saline source (Kevrekidis et al. 1990).*
- *Since it feeds primarily on benthic amphipods and polychaetes,* K. caucasica *prefers to inhabit sandy, muddy or gravel substrata (Kevrekidis et al. 1990, Daoulas et al. 1993)which may facilitate its survival during ballast water flushing.*
- *However, the species may have difficulty surviving adverse environments for long periods of time in ballast tanks. Typical environments they have been found in have a dissolved oxygen (DO) range of 5.3-8.4ppm and pH range of 7.3-8.3 (Kevrekidis et al. 1990). Low DO levels or acidic/basic conditions in ballast tanks may have adverse effects on their survival. Also, they can survive temperatures of 3.4°C up to 27°C, but temperatures above 15°C are ideal (Baimov 1963, Kevrekidis et al. 1990).*
- Knipowitschia caucasica *is found in the freshwater Lake Trichonis of Greece, and the Evros delta that has 24-36‰ salinity (Daoulas et al. 1993, Kevrekidis et al. 1993). This species occurs in waters with temperatures of 1.6-26.9°C and oxygen levels of 5.3-8.96 ppm (Kevrekidis et al. 1993, Gülle et al. 2008).*

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5 √
Yes, but this species has neither been observed in ballast/fouling ships entering the Great Lakes nor in ports in direct trade with the Great Lakes.	Score x 0.1
No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0
Unknown	U

- Knipowitschia caucasica *originates from the Ponto-Caspian region and has been confirmed in Aegean waters (Economidis and Miller 1990). Also, it has been identified in the Caspian, Azov, Aral, Black (Daoulas et al. 1993), and Adriatic (Kovačić and Pallaoro 2003) seas, as well as several localities in northern Greece and Turkey. Since ships coming from these locations have brought other invasive species (i.e. dreissenid mussels* *from Ponto-Caspian region), we know that ships have the potential to bring* K. caucasica *from these areas. However, documentation of* K. caucasica *in ballast water from these areas was not found.*

- *It occurs in the Mediterranean Sea (Kevrekidis et al. 1990), which has shipping traffic that goes directly to the Great Lakes; however, there is insufficient information to determine if this species occurs in the Mediterranean ports that are in direct trade with the Great Lakes.*

Vector Potential Scorecard					
Vector		**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind		**0**	x	**0**	Unlikely
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.		**0**	x	**0**	Unlikely
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)		**0**	x	**0**	Unlikely
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)		**0**	x	**0**	Unlikely
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)		**0**	x	**0**	Unlikely
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling		**80**	x 0.5	**40**	Moderate
Total Unknowns (U)	**0**	**Confidence Level**		High	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

ESTABLISHMENT POTENTIAL RESULTS

Status: **Not established in North America, including the Great Lakes**

Knipowitschia caucasica **has a moderate probability of establishment if introduced to the Great Lakes (Confidence level: Moderate).**

The native and introduced ranges of *Knipowitschia caucasica* have similar climatic and abiotic conditions as the Great Lakes (Grigorovich et al. 2003, Reid and Orlova 2002, USEPA 2008). This species inhabits shallow waters that have varied bottom structures (Kovačić and Pallaoro 2003), which are available in the Great Lakes region. *Knipowitschia caucasica* can tolerate a wide range of abiotic conditions. It resides in hypersaline and fresh waters (Kevrekidis et al. 1990), so it may survive the transition in salinity between ballast water and Great Lakes fresh water. It occurs in the eutrophic Lake Eğirdir (Gülle et al. 2008) as well as Lake Trichonis, a mesotrophic lake (Daoulas et al. 1993). It tolerates water temperatures of 1.6-26.9°C and oxygen levels of 5.3-8.96 ppm (Kevrekidis et al. 1990, Gülle et al. 2008); thus it is somewhat likely that this species can overwinter in the Great Lakes but its capacity to do so is limited by the amount of dissolved oxygen in the water. In its current range, *Knipowitschia caucasica* migrates into deeper waters over the winter (Baimov 1963) where temperatures may be slightly higher, but dissolved oxygen is lower. *Knipowitschia caucasica* prefers mesohaline to hypersaline waters; thus, increased salinization due to climate change would make the Great Lakes a better environment for the establishment of this species.

Knipowitschia caucasica has a broad and flexible diet, and feeds primarily on benthic amphipods, polychaetes, chironomid larvae, copepods, and cladocerans (Kevrekidis et al. 1990). These fish are also known to feed on *Dreissenid polymorpha* larvae (Daoulas et al. 1993), and may benefit from the presence of *Dreissenids* that are already established in the Great Lakes (Benson et al. 2014). Occasionally it feeds on planktonic organisms. It is likely that this species will find an appropriate food source in the Great Lakes. Larger fish in the Great Lakes may prey on *Knipowitschia caucasica* but it is unknown whether that would prevent establishment. In the Aral Sea, it is one of the most abundant fish and is not a very important component of the diets of piscivorous fish (Baimov 1963). It is unknown if the establishment of *Knipowitschia caucasica* will be prevented by parasitism. *Knipowitschia caucasica* is a host to parasites *Aphalloides coelomicola, Cryptocotyle spp., Paratimonia gobii, Timoniella imbutiforme,* and *Dichelyne minutus* (Krasnoyd et al. 2012); however, there is currently not enough information to determine if these parasites negatively impact the health of *Knipowitschia caucasica*, or its chances of establishing in the Great Lakes. *Aphalloides coelomicola* reduces the female gonad weight of the common goby (*Pomatoschistus microps*) (Pampouli et al. 1999). There is no evidence that suggest that *Aphalloides coelomicola*, *Cryptocotyle spp*., or *Paratimonia gobii* currently occur in the Great Lakes. *Timoniella spp.* has been found in the Great Lakes and reduces the ruffe's ability to survive in low oxygen waters (Pronin et al. 1997). *Dichelyne spp*. is reported to occur in the St. Lawrence River, but its occurrence and infection of native fish is low, and has not infected the nonindigenous round goby (Gendron et al. 2012).

Knipowitschia caucasica reproduces from the end of April to the end of July at water temperatures of 15-27°C (Kevrekidis et al. 1990). The Great Lakes basin contains a number of areas that have appropriate spawning temperatures during those months. *Knipowitschia caucasica* has a slightly lower fecundity than other fish in the *Knipowitschia* genus. Its lowest reported fecundity is 60 eggs (Kevrekidis et al. 1990) and its highest reported fecundity is 1389 eggs (Gheorghiev 1964). *K. longecaudata* has a fecundity of 350-2045 eggs (Zelenin and Vladimirov 1975, Ragimov 1986), and *K. iljini* has a fecundity of 2240 eggs

(Ragimov 1986). In the Caspian Sea, *Knipowitschia caucasica* had a moderate relative fecundity relative to the other *Knipowitschia* gobies.

Currently, there is no evidence indicating that *Knipowitschia caucasica* would outcompete other species in the Great Lakes if introduced. Its widespread distribution elsewhere has been attributed to its tolerance to a wide variety of environmental conditions, its non-specific diet, and early maturation (Kevrekidis et al. 1990). This species occurs in Lake Eğirdir, Lake Eber, and Demirköprü, and is speculated to have been introduced by anthropogenic means due to this fish's inability for natural introduction via crossing hydroelectric dams to migrate up strong currents from the Asku River (Van Neer et al. 1999). No specimens of *Knipowitschia caucasica* were found in these lakes prior to 1992, but were abundant in Lake Eğirdir by 1996, and were found in Lake Eber in 1997 and Demirköprü Dam Lake in 1998. There is a possibility that *Knipowitschia caucasica* was unintentionally introduced in these lakes with the stocking of common carp fry from Ipsala/Edirne hatcheries, which are located in the same region where this species is common. Kolar and Lodge (2002) predict that *Knipowitschia caucasica* may spread quickly after introduction using their models that take into account the fish's growth rate, lower survival in high water temperatures, and tolerance of a wide temperature range.

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
	7

- Knipowitschia caucasica *has wide ecological tolerances. It is a euryhaline species and can survive in both hypersaline and fresh water, allowing it to easy survive introduction to the Great Lakes from a saline source (Kevrekidis et al. 1990).*
- *This species occurs in waters with temperatures of 1.6-26.9°C (but temperatures above 15°C are ideal) and oxygen levels of 5.3-8.96 ppm (Kevrekidis et al. 1993, Gülle et al. 2008).*
- *The species has been found in Lake Trichonis in Greece, which is known for being mesotrophic (Daoulas et al. 1993). It occurs in the eutrophic Lake Eğirdir (Gülle et al. 2008).*
- *This species prefers shallower waters, with spawning typically occurring at 0.15 to 1.5 m (Baimov 1963).*
- *However, the species may be limited by low dissolved oxygen and pH conditions. Typical environments they have been found in have a dissolved oxygen (DO) range of 5.3-8.4 ppm and pH range of 7.3-8.3 (Kevrekidis et al. 1990).*

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9
Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
	6

- *This species occurs in waters with temperatures of 1.6-26.9°C (but temperatures above 15°C are ideal) and oxygen levels of 5.3-8.96 ppm (Kevrekidis et al. 1993, Gülle et al. 2008).*
- *After hatching in the spring, young* K. caucasica *typically grow rapidly in summer and autumn, and then mature after the first winter. They then spawn in warmer temperatures from the end of April through July (Kevrekidis et al. 1990).*
- *The species may have issues with low oxygen levels, as they have been found in environments with a dissolved oxygen range of 5.3-8.4ppm (Kevrekidis et al. 1990). Lower ranges have not been documented and this may be a limiting factor of this species success in the Great Lakes. However, the gobies have been found in freshwater lakes in Greece, Hungary, and Turkey that may have similar colder over-winter temperatures to the Great Lakes. For example,* K. caucasica *has been reported in Lake Trichonis, which is the largest and deepest natural freshwater body in Greece (Daoulas et al. 1993).*
- *It tolerates water temperatures of 1.6-26.9°C and oxygen levels of 5.3-8.96 ppm (Kevrekidis et al. 1990, Gülle et al. 2008); thus it is somewhat likely that this species can overwinter in the Great Lakes but its capacity to do so is limited by the amount of dissolved oxygen in the water. In its current range,* Knipowitschia caucasica *migrates into deeper waters over the winter (Baimov 1963) where temperatures may be slightly higher, but dissolved oxygen is lower. It occurs in waters that have ice cover in the winter (Reid and Orlova 2002).*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
	6

- *Stomach contents of* K. caucasica *revealed that they feed primarily on crustaceans and benthic invertebrates, specifically copepods and larval molluscs (dreissenids) (Daoulas et al. 1993).*
- *It has also been documented that they feed on amphipods and polychaetes (Kevrekidis et al. 1990).*
- *There is no evidence of this species feasting on planktonic invertebrates or fish.*

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9
Somewhat likely (This species is known to have superior competitive abilities, but there	6

are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	0
Unknown	U
	3

- *Currently, there is no evidence indicating that* Knipowitschia caucasica *would outcompete other species in the Great Lakes if introduced. Its widespread distribution elsewhere has been attributed to its tolerance to a wide variety of environmental conditions, its non-specific diet, and early maturation (Kevrekidis et al. 1990).*
- *In the Aral Sea, it is one of the most abundant fish and is not a very important component of the diets of piscivorous fish (Baimov 1963).*
- *However, this goby species has a relatively high rate of reproduction, early sexual maturation (at 20-23 mm), and after 8-10 months post hatching they have a high gonadosomatic index (Economidis and Miller 1990). The rapid reproduction of this species may allow them to outcompete some slower growing species for resources and breeding habitats.*
- *Literature does not show evidence of the species outcompeting other goby or fish species in its native region, or evidence of it being a poor competitor. Also, in environments where similar goby species are present (i.e.* E. pygmaeus*), the larval forms were observed to share aquatic vegetation habitat, but showed different habitat preference later in life (Daoulas et al. 1993).*
- *Currently, there is no evidence indicating that* Knipowitschia caucasica *would outcompete other species in the Great Lakes if introduced. Its widespread distribution elsewhere has been attributed to its tolerance to a wide variety of environmental conditions, its non-specific diet, and early maturation (Kevrekidis et al. 1990).*

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
	3

- Knipowitschia caucasica *has a relatively high rate of reproduction, early sexual maturation (at 20-23 mm), and after 8-10 months post hatching they have a high gonadosomatic index (Economidis and Miller 1990).*
- *Two other goby species that are endemic to the same regions as* K. caucasica *(*Economidichthys pygmaeus *and* E. trichonis*) spawn earlier between late February through May (Daoulas et al. 1993).* K. caucasica *breeds typically from end of April through July (Kevrekidis et al. 1990).*
- Economidichthys pygmaeus *has been reported to lay about 500 eggs per nest and* E. trichonis *about 200-300 eggs per nest (Daoulas et al. 1993). Reports of* K. caucasica *nesting report each spawning batch consisting of 80-100 cylindrical eggs, with only about 50 successfully hatching after 6 days incubation (Economou et al. 1994).*
- Knipowitschia caucasica *has a slightly lower fecundity than other fish in the Knipowitschia genus. Its lowest reported fecundity is 60 eggs (Kevrekidis et al. 1990) and its highest reported fecundity is 1389 eggs*

(Gheorghiev 1964). K. longecaudata *has a fecundity of 350-2045 eggs (Zelenin and Vladimirov 1975; Ragimov 1986), and* K. iljini *has a fecundity of 2240 eggs (Ragimov 1986). In the Caspian Sea,* Knipowitschia caucasica *had a moderate relative fecundity relative to the other Knipowitschia gobies.*

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
	0

- *This species has been shown to prefer aquatic vegetative habitats during its larvae stage and has been shown to form nests in aquatic reeds (Daoulas et al. 1993), but unlike other related goby species that prefer deeper areas covered in weeds, this species prefers shallower sandy, muddy substrata close to shore (Daoulas et al. 1993). However, other than habitat preference, evidence of other reproductive strategies was not found.*

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- *This species has been reported in the Ponto-Caspian region, particularly in Hungary (Halasi-Kovács et al. 2011), Turkey (Van Neer et al. 1999), Greece (Economidis and Miller 1990, Kevrekidis et al. 1990, Daoulas et al. 1993) and in the Adriatic Sea (Kovačić and Pallaoro 2003). All of these regions are within similar latitudes as the Great Lakes region.*
- *This species in its native ranges is adjusted to hatching in summer/autumn (July/September) at temperatures around 25-28°C and overwintering at temperatures around 3-5°C (Kevrekidis et al. 1990). These are climatic conditions and seasonality almost identical to the Great Lakes region.*

- *Ponto-Caspian region has similar climate and abiotic conditions as Great Lakes (Grigorovich et al. 2003, Reid and Orlova 2002, USEPA 2008).*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- *This species has been reported in large seas such as Caspian, Azov, Aral and Black Seas, as well as several northern localities of Greece and Turkey (Daoulas et al. 1993).*
- Knipowitschia caucasica *has wide ecological tolerances. It is a euryhaline species and can survive in both hypersaline and fresh water, allowing them to easy survive introduction to the Great Lakes from a saline source (Kevrekidis et al. 1990). In addition, it has demonstrated the ability to develop freshwater populations in European riverine and lake systems (Halasi-Kovács et al. 2011).*
- *This species in its native ranges is adjusted to hatching in summer/autumn (July/September) at temperatures around 25-28°C and overwintering at temperatures around 3-5°C (Kevrekidis et al. 1990). These are water conditions similar to the Great Lakes region.*
- *No evidence was found on the species chemical tolerances or required nutrient levels.*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0
Unknown	U
	8

- *This species prefers the shallow waters of mesohaline coastal lakes and lagoons (Kevrekidis et al. 1990); however, they have been found in a variety of different salinities, from fresh to sea water (0-24.5 PSU;(Kovačić and Pallaoro 2003). The Great Lakes has several areas of freshwater coastline that has shallow marshes and several shallow inland lakes.*
- *Recently,* K. caucasica *has been found in a medium flow, 2-4 m depth river in Hungary (Halasi-Kovács et al. 2011). Similar habitats are also available in the Great Lakes basin.*
- *This species in its native ranges is adjusted to hatching in summer/autumn (July/September) at temperatures around 15-27°C (Kevrekidis et al. 1990). These are water conditions similar to the Great Lakes region.*
- *In order for the species to invade some of the inland lakes in Turkey and Greece, Van Neer et al. (1999) argues that the gobies cannot overcome strong currents of rivers and connection canals, therefore, they must have been*

introduced by human activities. The strong currents and deep waters of the Great Lakes may pose a challenge for this species to invade some of the shallower waters of the Great Lakes region.

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0
Unknown	U
	6

- *This species prefers the shallow waters of mesohaline and hypersaline coastal lakes and lagoons (Kevrekidis et al. 1990);therefore, increased salinization in the Great Lakes due to climate change would benefit the species.*
- *In addition, this species grows rapidly in the summer and autumn during the warmer months (July-Sept) (Kevrekidis et al. 1990).*
- *However, the effects of climate change on this species has not been specifically studied, so its actual response is still unknown.*

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
	9

- Knipowitschia caucasica *feeds predominately on benthic amphipods and polychaetes (Kevrekidis et al. 1990). Stomach contents of* K. caucasica *also revealed crustaceans and other benthic invertebrates, including copepods and larval mollusks (dreissenids;(Daoulas et al. 1993)). Given the large variety of aquatic benthic invertebrates in the Great Lakes and the invasian of the zebra and quagga mussels (dreissenids),* K. caucasica *will have abundant food sources in the Great Lakes.*
- Knipowitschia caucasica *has a broad and flexible diet, and feeds primarily on benthic amphipods, polychaetes, chironomid larvae, copepods, and cladocerans (Kevrekidis et al. 1990). These fish are also known to feed on*

Dreissenid polymorpha *larvae (Daoulas et al. 1993), and may benefit from the presence of dreissenids that are already established in the Great Lakes (Benson et al. 2014).*

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Great Lakes and is not likely to be introduced	-80% total points (at end)
Unknown	U
	9

- *No documentation was found indicating any symbiotic relationships necessary for species survival.*

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes)	6
Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0
Unknown	U
	6

- *Because* K. caucasica *feeds heavily on dreissenid mussel larvae (Daoulas et al. 1993), the abundance of dreissenid mussels in the Great Lakes may provide a sufficient food source for goby establishment.*

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0
Unknown	U
	U

- *Given the very small size of* K. caucasica *(30-50 mm in length), it may be eaten by larger piscivorous fish that are prevalent in the Great Lakes. However, there is no literature supporting piscivorous fish preventing the establishment of this species in its native range.*
- *Larger fish in the Great Lakes may prey on* Knipowitschia caucasica *but it is unknown whether that would prevent establishment. In the Aral Sea, it is one of the most abundant fish and is not a very important component of the diets of piscivorous fish (Baimov 1963).*
- *It is unknown if the establishment of* Knipowitschia caucasica *will be prevented by parasitism. Knipowitschia caucasica is a host to parasites* Aphalloides coelomicola*,* Cryptocotyle *spp.,* Paratimonia gobii, Timoniella imbutiforme*, and* Dichelyne minutus *(Krasnoyd et al. 2012); however, there is currently not enough information to determine if these parasites negatively impact the health of* Knipowitschia caucasica*, or its chances of establishing in the Great Lakes.*
- Aphalloides coelomicola *reduces the female gonad weight of the common goby (*Pomatoschistus microps*) (Pampouli et al. 1999). There is no evidence that suggest that* Aphalloides coelomicola*,* Cryptocotyle *spp., or* Paratimonia gobii *currently occur in the Great Lakes.* Timoniella *spp. has been found in the Great Lakes and reduces the ruffe's ability to survive in low oxygen waters (Pronin et al. 1997).* Dichelyne *spp. is reported to occur in the St. Lawrence River, but its occurrence and infection of native fish is low, and has not infected the nonindigenous round goby (Gendron et al. 2012).*

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9
Frequent, moderate inocula	6
Frequent, small inocula OR infrequent, large inocula	3
Infrequent, small or moderate inocula	0

Unknown	U
	U

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
	4

- *This species is found primarily in the Ponto-Caspian region but has established in several areas outside its native range including the Northern Aegean Sea (Economidis and Miller 1990, Kevrekidis et al. 1990), Azov Sea, Aral Sea, and Black Sea (Daoulas et al. 1993), Adriatic Sea (Kovačić and Pallaoro 2003), inland Turkish lakes (Van Neer et al. 1999), Szamos River in Hungary (Halasi-Kovács et al. 2011), and Lake Pamvotis in NW Greece (Leonardos et al. 2008).*
- *Van Neer (1999) argues that the majority of invasions are caused by introduction by man, most likely with fish stocks and recreational activities.*

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
	3

- *This species occurs in Lake Eğirdir, Lake Eber, and Demirköprü, and is speculated to have been introduced by anthropogenic means due to this fish's inability to cross hydroelectric dams to migrate up strong currents from the Asku River (Van Neer et al. 1999). No specimens of* Knipowitschia caucasica *were found in these lakes prior to 1992, but were abundant in Lake Eğirdir by 1996, and were found in Lake Eber in 1997 and Demirköprü Dam Lake in 1998. There is a possibility that* Knipowitschia caucasica *was unintentionally introduced in these lakes with the stocking of common carp fry from Ipsala/Edirne hatcheries, which are located in the same region where this species is common.*

- *The authors predict that this species may spread quickly using their models that take into account the fish's growth rate, survival in high temperatures, and tolerance of a wide temperature range (Kolar and Lodge 2002).*

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing the establishment and spread of this species)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent the establishment and/or spread of this species	0
Unknown	U
	0

- *Given that the primary mode of introduction for this species will be through ballast water tanks, current treatments of ballast water entering the Great Lakes may help to prevent the establishment of the species. However, it is unknown how these treatments will affect this species.*
- *The treatment of ballast water by water exchange in the ocean may not effect this species due to their euryhaline nature and ability to withstand salinities from 60-24.5PSU (Kovačić and Pallaoro 2003).*

Establishment Potential Scorecard				
Points	**Probability for Establishment**	A. Total Points (pre-adjustment)		86
>100	High	**Adjustments**		
		B. Critical species	A*(1- 0%)	86
51-99	Moderate	C. Natural enemy	B*(1-0%)	86
		Control measures	C*(1- 0%)	86
0-50	Low	**Potential for Establishment**		Moderate
# of questions answered as "unable to determine"	**Confidence Level**			
0-1	High	Total # of questions unknown		2
2-5	Moderate			
6-9	Low	Confidence Level		Moderate
>9	Very low			

Section C: Potential for Impact

IMPACT POTENTIAL RESULTS

Environmental: Unknown

Socio-Economic: Low

Beneficial: Low

Current research on the potential for environmental impacts to result from *Knipowitschia caucasica* if introduced to the Great Lakes is inadequate to support proper assessment.

There is no evidence that suggests that *Knipowitschia caucasica* poses a threat to native species or outcompetes native species for resources. There are no reports on how it affects or interacts with other species. There is insufficient information available to determine whether *Knipowitschia caucasica* reduces water quality. It is unknown whether this species alters the physical components of the ecosystem.

There is little or no evidence to support that *Knipowitschia caucasica* has the potential for significant socio-economic impacts if introduced to the Great Lakes.

It has not been reported that *Knipowitschia caucasica* poses a threat to human health or water quality. There is no evidence that this species negatively impacts infrastructure, economic sectors, recreational activities and associated tourism, or the aesthetic appeal of the areas it inhabits.

There is little or no evidence to support that *Knipowitschia caucasica* has the potential for significant beneficial impacts if introduced to the Great Lakes.

It is unknown whether *Knipowitschia caucasica* can act as a biological control agent. Dressenid mussel larvae are part of their diet (Daoulas et al. 1993), but it is unknown whether this will significantly control dressenid populations. It is not known to be commercially, recreationally, or medically valuable. This species does not improve water quality or have positive ecological impacts.

POTENTIAL ENVIRONMENTAL IMPACT

NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1

Not significantly	0 √
Unknown	U

- *While this species has been studied, there is no evidence of it causing any adverse effects on other species, especially due to toxins, poisons, or pathogens.*

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1
Not significantly	0 √
Unknown	U

- *The rapid growth and reproduction of the species has been well documented (Economidis and Miller 1990, Kevrekidis et al. 1990, Economou et al. 1994), but there is no evidence of these characteristics* causing K. caucasica *to out-compete other species.*

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in the food web)	6
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	1
Not significantly	0
Unknown	U √

- *Predatory responses of the species have not been studied, nor is there any documentation of the species affecting other predator-prey interactions.*

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0
Unknown	U √

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1
Not significantly	0
Unknown	U √

- *While* K. caucasica *is primarily a benthic feeder (Kevrekidis et al. 1990), there is no evidence that it disturbs the sediments and causes a significant increase in turbidity.*
- *Other parameters, such as altered nutrients, oxygen, or chemical levels have not been studied in this species or similar species.*

E6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1
Not significantly	0 √
Unknown	U

- *Again, while* K. caucasica *is primarily a benthic feeder (Kevrekidis et al. 1990), there is no evidence that it disturbs the sediments and causes a significant increase in erosion. Documentation of other physical alterations of the ecosystem have not been documented.*

Environmental Impact Total	**0**
Total Unknowns (U)	**3**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	Low
1	0	
0	≥2	**Unknown**
1	≥1	

POTENTIAL SOCIO-ECONOMIC IMPACT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1
Not significantly	0 √
Unknown	U

- *There is no information on disease or parasite transmission by this species to humans.*

S2) Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1
Not significantly	0 √
Unknown	U

S3) Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0 √
Unknown	U

S4) Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

Socio-Economic Impact Total	**0**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**Low**
1	0	
0	≥2	Unknown
1	≥1	

POTENTIAL BENEFICIAL EFFECT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular effect. An "Unknown" response is appropriate if the potential for a particular effect might be inferred but has not been explicitly reported or if there is an unresolved debate about a particular effect.

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1

Not significantly	0
Unknown	U √

- Knipowitschia caucasica *primary habitat is shallow coastal lakes and lagoons (Kevrekidis et al. 1990), and it has been documented in riverine systems (Halasi-Kovács et al. 2011). It usually prefers bare rock or vegetation, with varied substrate from mud to gravel, course sands, and boulders (Kovačić and Pallaoro 2003).*
- *This species lays its eggs attached to the underside of small gravels, dead bivalve shells, dead roots of reeds, etc. and require this type of foliage for building their nests (Baimov 1963). However, there is no evidence of the species controlling aquatic weeds.*
- *Since dreissenid mussel larvae are an important food item for* K. caucasica *(Daoulas et al. 1993), it may be able to aid in controlling dreissenid mussel populations.*
- *No evidence of the species controlling other nonindigenous organisms.*

B2) Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?

Yes, it is economically important to at least one of these industries	6
Yes, but its economic contribution is small	1
Not significantly	0 √
Unknown	U

- *Performing an online search of aquaria, catalogs, and biological supply companies (including Carolina Biological, Aquatic Biosystems, and Fisher-Scientific) did not yield any listings or information for* K. caucasica *or the common name (Caucasian dwarf goby). There does not appear to be a market for this fish species; however, there may be some individuals who would like to purchase this species for personal fish tanks.*
- *The small size of the species may also make it ideal as bait for larger Great Lakes fish.*

B3) Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local communities and/or tourism	6
It is sometimes employed recreationally, but adds little value to local communities or tourism	1
Not significantly	0 √
Unknown	U

- *While this species is not fished for recreational in its native ranges, it is frequently found in other fish hauls and in fish stocks (Daoulas et al. 1993, Van Neer et al. 1999).*
- *While there does not appear to be a market for this species, some individuals may like to purchase this species for personal fish tanks.*
- *The small size of the species may also make it ideal as bait for larger Great Lakes fish.*

B4) Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR It is potentially important to medicine or research and is currently being or scheduled to be studied	1

Not significantly	0 √
Unknown	U

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1
Not significantly	0 √
Unknown	U

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1
Not significantly	0 √
Unknown	U

Beneficial Effect Total	**0**
Total Unknowns (U)	**1**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**<u>Low</u>**
1	0	
0	≥2	Unknown
1	≥1	

Scientific Name: *Leuciscus idus*
Linnaeus, 1758

Common Name: Golden Orfe, Ide

Synonyms:

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: Unknown

Hitchhiking/fouling: Unlikely

Unauthorized intentional release: High

Stocking/planting/escape from recreational culture: High

Escape from commercial culture: Unlikely

Transoceanic shipping: Unlikely

***Leuciscus idus* has a high probability of introduction to the Great Lakes (Confidence level: Moderate).**

Potential pathway(s) of introduction: Dispersal, Unauthorized Intentional Release, Escape from Recreational Culture

Leuciscus idus has been recorded in nine states, but the documentation of its true status in the United States is poor and often contradictory. It was collected in the Chenango River (tributary to the Susquehanna River), between Hamilton and Norwich, **New York**, in the early 1950s (Courtenay et al. 1984) and also Cortland County ca. 1954 (Courtenay, personal communication). There are reports from unspecified waters in **Illinois, Indiana**, and **Minnesota** in the 1890s (Nico et al. 2012).

Leuciscus idus is not known to be commercially cultured in the Great Lakes region but is sold as a pond fish in the Great Lakes region (e.g., William Tricker, Inc. in Independence, Ohio) and online hobbyists report keeping this fish in **Michigan**.

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100
No, this species does not occur near waters connected to the Great Lakes basin and/or is	0

not mobile or able to be transported by wind or water.	
Unknown	U √

- Leuciscus idus *has been recorded from nine states, but the documentation of its true status in the United States is poor and often contradictory. It was collected in the Chenango River (tributary to the Susquehanna River), between Hamilton and Norwich, New York, in the early 1950s (Courtenay et al. 1984) and also Cortland County ca. 1954 (Courtenay, personal communication). There are reports from unspecified waters in Illinois, Indiana, and Minnesota in the 1890s (Nico et al. 2012).*

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25
Unknown	U √

- Leuciscus idus *has been recorded from nine states, but the documentation of its true status in the United States is poor and often contradictory. It was collected in the Chenango River (tributary to the Susquehanna River), between Hamilton and Norwich, New York, in the early 1950s (Courtenay et al. 1984) and also Cortland County ca. 1954 (Courtenay, personal communication). There are reports from unspecified waters in Illinois, Indiana, and Minnesota in the 1890s (Nico et al. 2012).*

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0 √
Unknown	U

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a) Is this species sold at aquarium/pet/garden stores ("brick & mortar" or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100 √
No, this species this species is rarely/never sold.	0
Unknown	U

- *This species is being sold as a pond fish (e.g., William Tricker, Inc. in Independence, Ohio).*

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1 √
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1
Unknown	U

- *This species is being sold as a pond fish (e.g., William Tricker, Inc. in Independence, Ohio).*

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100 √
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0
Unknown	U

- *This species is being sold as a pond fish (e.g., William Tricker, Inc. in Independence, Ohio).*

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1 √
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is <u>likely</u> to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces), this activity <u>may</u> occur within 20 km of the basin because of the species' popularity/value.	Score x 0.25
Unknown	U

- *This species is being sold as a pond fish (e.g., William Tricker, Inc. in Independence, Ohio).*
- *Online hobbyists report keeping this fish in Michigan.*

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100
No, this species is not commercially cultured in or transported through the Great Lakes region.	0 √
Unknown	U

- *This fish is not known to be commercially cultured or transported through the Great Lakes region.*

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40
No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0 √
Unknown	U

- *This fish is not likely to be taken up in ballast or survive those conditions.*

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5
Yes, but this species has neither been observed in ballast/fouling ships entering the Great Lakes nor in ports in direct trade with the Great Lakes.	Score x 0.1
No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0
Unknown	U

Vector Potential Scorecard				
Vector	**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind	**U**	x U	**U**	Unknown
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.	**0**	x	**0**	Unlikely
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)	**100**	x 1	**100**	High
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)	**100**	x 1	**100**	High
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)	**0**	x	**0**	Unlikely
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling	**0**	x	**0**	Unlikely
Total Unknowns (U)	**2**	**Confidence Level**	Moderate	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	**Confidence Level**

0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

ESTABLISHMENT POTENTIAL RESULTS

Status: **Not likely established in North America, including the Great Lakes**

***Leuciscus idus* has a moderate probability of establishment if introduced to the Great Lakes (Confidence level: Moderate).**

This species is found in both freshwater and brackish habitats (Muus and Dahlstrom 1978). However, they do show reduced foraging success in turbid waters (Kuliskova et al. 2009).

While this species is not well studied, it lives in a variety of waters from the heavily industrialized, polluted Vistula River in Poland, to the pristine Pechora River basin in northwest Russia. Thus, it would likely experience a range of abiotic factors, some of which would be similar to the Great Lakes. It is found in both large rivers and nutrient-rich lakes (Froese 2013). *Leuciscus idus* tolerates a wide range of conditions (Seeley 1962) and can successfully reproduce in waters 8-23°C (Kupren et al. 2011). *Leuciscus idus* are native to northern Europe through Siberia (Berg 1949, Robins et al. 1991). As the winter temperatures in this region are colder than the Great Lakes, this species is likely to overwinter in the Great Lakes successfully. This species eats larval and adult insects, snails, and other invertebrates; larger individuals also take small fish (Phillips and Rix 1985).

Successive year-class strengths and growth rates in northern environments are also likely to increase as temperatures increase. Evidence that northward colonization is already occurring comes from Russia (Wrona et al. 2010). Over the last 10 to 15 years, Ide (*Leuciscus idus*) have become much more numerous in the Pechora River Delta and the estuary Sredinnaya Guba (~68° N) of the Barents Sea (Wrona et al. 2010). A study from Poland confirmed that *L. idus* embryos can accommodate water temperature increases up to 23°C (Kupren et al. 2011).

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3

Unknown	U
	7

- Leuciscus idus *can successfully reproduce in waters 8-23°C (Kupren et al. 2011).*
- *This species can tolerant to a wide range of conditions (Seeley 1962).*
- *This species found in freshwater and brackish habitats (Muus and Dahlstrom 1978).*
- *This species has reduced foraging success in turbid waters (Kuliskova et al. 2009).*

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9
Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
	9

- Leuciscus idus *is native to northern Europe through Siberia (Nico et al. 2012). As the temperatures in this region are colder in the Great Lakes, this species is likely to overwinter in the Great Lakes successfully.*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
	7

- Leuciscus idus *eats larval and adult insects, snails, and other invertebrates; larger individuals also take small fish (Nico et al. 2012).*

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	6
Somewhat unlikely (This species has average competitive abilities, and there are no	3

reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	0
Unknown	U
	U

- *This species has not been studied well.*

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
	9

- Leuciscus idus *has a relative fecundity mean of 44,621 eggs/kg (Targónska et al. 2012).*
- *Other cyprinids:*
    - *Relative fecundity of* Carassius carassius *reported as 119.2;* Carassius auratus *reported relative fecundity of 251.7 (Copp et al. 2010) and 270 (Tarkan et al. 2010).*
    - *Relative fecundity of* Carassius gibelio *was 78-251 (Leonardos et al. 2008)*
    - *Other minnow species in the family Cyprinidae, subfamily Leuciscinae, include: Fathead Minnow (*Pimephales promelas*), 6803-10164 eggs per season, also a batch spawner (Gale and Buynak 1982); Bluntnose Minnow (*Pimephales notatus*), 1112-4195 eggs per season, also a batch spawner (Gale 1983); Red Shiner (*Notropis lutrensis*), 4701-8248 eggs per season, also a batch spawner (Gale 1986); Emerald Shiner (*Notropis atherinoides*), mean 3410 eggs per season (Campbell and MacCrimmon 1970).*

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0

Unknown	U
	0

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	7

- Leuciscus idus *is native to northern Europe through Siberia (Nico et al. 2012). The Siberian climate is quite varied, but has an average of high in January of 10F, an average high in July of 78.2. Precipitation is low in the north, but high in the south with heavy summer rainfall (up to 850mm).*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	6

- *Sensitivity to several chemicals of* L. idus *was similar to Rainbow Trout and Minnow* Phoxinus laevis *(Hamburger et al. 1977).*
- *While this species is not well studied, it lives in a variety of waters from the heavily industrialized, polluted Vistula River in Poland, to the pristine Pechora River basin in northwest Russia. Thus, it would likely experience a range of abiotic factors, some of which would be similar to the Great Lakes.*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by	6

species already present)	
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0
Unknown	U
	7

- Leuciscus idus *is found in large rivers and nutrient-rich lakes (Froese 2013).*
- *This species spawns in tributaries, eggs attached to gravel, weed and stones in shallow water (Froese 2013).*
- *Juveniles prefer water depth up to 2 m and flow velocities of about 0.5 m (Grift et al. 2001).*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0
Unknown	U
	5

- *Successive year-class strengths and growth rates in northern environments are also likely to increase as temperatures increase. Evidence that northward colonization is already occurring comes from Russia. Over the last 10 to 15 years, ide (*Leuciscus idus*) have become much more numerous in the Pechora River Delta and the estuary Sredinnaya Guba (~68° N) of the Barents Sea (Wrona et al. 2010).*
- *A study from Poland confirmed that* L. idus *embryos can accommodate water temperature increases up to 23°C (Kupren et al. 2011).*
- *However, given the northern most sections of the Great Lakes are currently inhabitable by* L. idus*, climate change would not significantly benefit this species.*

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Great Lakes that may	0

be considered potential food items—are relatively scarce and/or search time is high)	
Unknown	U
	7

- Leuciscus idus *eats larval and adult insects, snails, and other invertebrates; larger individuals also take small fish (Nico et al. 2012).*

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Great Lakes and is not likely to be introduced	-80% total points (at end)
Unknown	U
	9

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes)	6
Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0

Unknown	U
	0

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0
Unknown	U
	0

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9
Frequent, moderate inocula	6
Frequent, small inocula OR infrequent, large inocula	3
Infrequent, small or moderate inocula	0
Unknown	U
	U

- *This would depend on popularity of this species as a backyard pond inhabitant, which is unknown.*

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6

Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
	9

- Leuciscus idus *has been introduced to United Kingdom, Netherlands, New Zealand, US, and France (GISD 2010).*

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
	3

- *This species has not been well studied and has no widespread reported impacts, which would suggest it has not become highly invasive and spread extensively. However, it is widespread in the United Kingdom.*

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing the establishment and spread of this species)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent the establishment and/or spread of this species	0
Unknown	U
	0

Establishment Potential Scorecard				
Points	**Probability for Establishment**	A. Total Points (pre-adjustment)		85
>100	High	**Adjustments**		
		B. Critical species	A*(1- 0%)	85
51-99	Moderate	C. Natural enemy	B*(1- 0%)	85
		Control measures	C*(1- 0%)	85
0-50	Low	**Potential for Establishment**		Moderate
# of questions answered as "unable to determine"	**Confidence Level**			
0-1	High	Total # of questions unknown		2
2-5	Moderate			
6-9	Low	Confidence Level		Moderate
>9	Very low			

Section C: Potential for Impact

IMPACT POTENTIAL RESULTS

Environmental: Unknown

Socio-Economic: Low

Beneficial: High

Current research on the potential for environmental impacts to result from *Leuciscus idus* if introduced to the Great Lakes is inadequate to support proper assessment.

There is insufficient information available to determine whether *Leuciscus idus* poses a threat to other species or water quality. There are no reports on how it affects or interacts with other species. It is unknown whether this species alters the physical components of the ecosystem.

The main concern about this species in the Great Lakes results from relationship to invasive *Cyprinus carpio* (GISD 2010). There is some concern it may outcompete native species, though has not been well studied. *Leuciscus idus* has been found to host the myxospridian parasite, *Thelohanellus oculileucisci* in Poland; but effects on fish were not mentioned (Jezewski and Kamara 1999). This species has also been found to host the hexamitid flagellate, *Spironucleus vortens*, which may transfer from cultured to wild populations (Sterud and Poynton 2002).

There is little or no evidence to support that *Leuciscus idus* has the potential for significant socio-economic impacts if introduced to the Great Lakes.

It has not been reported that *Leuciscus idus* poses a threat to human health or water quality. There is no evidence that this species negatively impacts infrastructure, economic sectors, recreational activities and associated tourism, or the aesthetic appeal of the areas it inhabits.

***Leuciscus idus* has the potential for high beneficial impact if introduced to the Great Lakes.**

Leuciscus idus has a huge economic value in Poland, as well as many other European countries, because its production is very high in comparison to other rheophilic cyprinids and it is produced as a market and sport fish. In addition, the ornamental form of this species (golden orfe) is also cultured. For example, between 2000 and 2002, the production of *L. idus* summer fry for restocking was about 4,700,000 specimens. One-year-old fish production (2004) was about 27,000 kg, which is 69% and 91% of the total production of riverine cyprinids for 2000 and 2002, respectively (Targónska et al. 2011). *Leuciscus idus* has been popular among anglers in some countries (Turkowski et al. 2008, GISD 2010, Kupren et al. 2011).

POTENTIAL ENVIRONMENTAL IMPACT

NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1
Not significantly	0
Unknown	U √

- Leuciscus idus *has been found to host the myxospridian parasite,* Thelohanellus oculileucisci *in Poland; effects on fish not mentioned (Jezewski and Kamara 1999).*
- *This species has been found to host the hexamitid flagellate* Spironucleus vortens*, which may transfer from cultured to wild populations (Sterud and Poynton 2002).*

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1
Not significantly	0
Unknown	U √

- *There is some concern it may outcompete native species, though has not been well studied. Main concern results from relationship to invasive Cyprinus carpio (GISD 2010).*

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in the food web)	6
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	1
Not significantly	0 √
Unknown	U

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0 √
Unknown	U

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1
Not significantly	0 √
Unknown	U

E6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6

Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1
Not significantly	0 √
Unknown	U

Environmental Impact Total	**0**
Total Unknowns (U)	**2**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	Low
1	0	
0	≥2	**Unknown**
1	≥1	

POTENTIAL SOCIO-ECONOMIC IMPACT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1
Not significantly	0 √
Unknown	U

S2) Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1
Not significantly	0 √
Unknown	U

S3) Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0 √
Unknown	U

S4) Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

Socio-Economic Impact Total	**0**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High

2-5	Any	Moderate
0	0-1	**Low**
1	0	
0	≥2	Unknown
1	≥1	

POTENTIAL BENEFICIAL EFFECT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular effect. An "Unknown" response is appropriate if the potential for a particular effect might be inferred but has not been explicitly reported or if there is an unresolved debate about a particular effect.

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1
Not significantly	0 √
Unknown	U

B2) Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?

Yes, it is economically important to at least one of these industries	6 √
Yes, but its economic contribution is small	1
Not significantly	0
Unknown	U

- Leuciscus idus *has a huge economic value in Poland, as well as many other European countries, because its production is very high in comparison to other rheophilic cyprinids and it is produced as a market and sport fish. In addition, the ornamental form of this species (golden orfe) is also cultured. For example, between 2000 and 2002, the production of* L. idus *summer fry for restocking was about 4,700,000 specimens. One-year-old fish production (2004) was about 27,000 kg, which is 69% and 91% of the total production of riverine cyprinids for 2000 and 2002, respectively (Targónska et al. 2011).*

B3) Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local communities and/or tourism	6
It is sometimes employed recreationally, but adds little value to local communities or tourism	1 √
Not significantly	0
Unknown	U

- Leuciscus idus *has some popularity for anglers in some countries (Turkowski et al. 2008, Kupren et al. 2011).*

B4) Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR It is potentially important to medicine or research and is currently being or scheduled to be studied	1 √
Not significantly	0
Unknown	U

- *Used in research: thermal adaptation in liver function (Braunbeck et al. 1987), chemical toxicity (Braunbeck and Segner 1992).*

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1
Not significantly	0 √
Unknown	U

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1
Not significantly	0 √
Unknown	U

Beneficial Effect Total	**8**
Total Unknowns (U)	**0**

Scoring		
Score	# U	**Impact**
>5	Any	<u>**High**</u>
2-5	Any	Moderate
0	0-1	Low
1	0	

0	≥2	Unknown
1	≥1	

Scientific Name: *Leuciscus leuciscus*
Linnaeus, 1758

Common Name: Eurasian Dace

Synonyms:

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: Unlikely

Hitchhiking/fouling: Unlikely

Unauthorized intentional release: Unlikely

Stocking/planting/escape from recreational culture: Unlikely

Escape from commercial culture: Unlikely

Transoceanic shipping: Moderate

***Leuciscus leuciscus* has a moderate probability of introduction to the Great Lakes (Confidence level: High).**

Potential pathway(s) of introduction: Transoceanic Shipping (ballast water)

Leuciscus leuciscus does not currently occur near waters connected to the Great Lakes basin. It is not known to be able to attach to recreational gear, fauna, flora, or other objects to be later transported to the Great Lakes. This species is not stocked, cultured, or sold in the Great Lakes region. This species is found in the River Exe in south-west and River Thames in England (Cowx 1988, Araújo et al. 1999), Munster Blackwater in Ireland (Caffrey et al. 2007), and the Baltic Sea (Voipio 1981). This species occurs in ports that have direct trade connections with the Great Lakes (NBIC). It is found in waters with high levels of dissolved oxygen, so it is unlikely to be capable of surviving ballast tank environments for weeks at a time. *Leuciscus leuciscus* cannot tolerate high salinities of full strength seawater, so ballast water regulations may prevent the introduction of this species to the Great Lakes. *Leuciscus leucisus* may be introduced to the Great Lakes via ships declaring “No Ballast on Board” (NOBOB), which are exempt from ballast water exchange. The majority of ships entering the Great Lakes are NOBOB vessels and 43% of these ships contain residual water with less than 10‰ salinity (Johengen et al. 2005). In the study, the temperature of the residual water from the vessels sampled ranged from -0.7 to 23.9°C; thus *Leuciscus leuciscus* is somewhat likely to survive the salinity and temperature of NOBOB ballast water on some ships. The eggs of *Leuciscus leuciscus* stick to substrates (Mills 1981), but it is unknown whether they would stick to transoceanic ship structures.

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100
No, this species does not occur near waters connected to the Great Lakes basin and/or is not mobile or able to be transported by wind or water.	0 √
Unknown	U

- *Dace is present throughout Europe from Scandinavia to south France into the former Soviet Union. Ireland represents its most westward presence (Wheeler 1969, Caffrey et al. 2007)*

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0 √
Unknown	U

- *The eggs of* Leuciscus leuciscus *stick to substrates (Mills 1981), but it is unknown whether they would stick to transoceanic ship structures.*

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a) Is this species sold at aquarium/pet/garden stores ("brick & mortar" or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100
No, this species this species is rarely/never sold.	0 √
Unknown	U

- *This species is sold as live bait in European countries, however is not found for sale within the Great Lakes basin.*

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0 √
Unknown	U

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is likely to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces), this activity may occur within 20 km of the basin because of the species' popularity/value.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100
No, this species is not commercially cultured in or transported through the Great Lakes region.	0 √
Unknown	U

- *Turkowski et al. (2008) evaluated the profitability of culturing the dace* Leuciscus leuciscus*, as a restoration effort in parts of Europe. There is no evidence of commercial culture being in use today.*

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80 √
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40
No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0
Unknown	U

- *Dace is commonly associated with high levels of dissolved oxygen and low pH; it is also only tolerant to mild brackish salinities (Araújo et al. 1999).*
- *Although Dace is tolerant to some salinities, it is not likely to survive higher salinities encountered during ballast water exchange (Araújo et al. 1999).*

- *Dace live in swift streams and rivers with rocky bottoms (Miller and Loates 1997).*
- *Juvenile Dace tend to live in shallow habitats along the shore (Kottelat and Freyhof 2007).*
- *Dace have been present in brackish estuaries of surveyed rivers, though is unable to travel to more saline waters closer to sea (Caffrey et al. 2007).*

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5 √
Yes, but this species has neither been observed in ballast/fouling ships entering the Great Lakes nor in ports in direct trade with the Great Lakes.	Score x 0.1
No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0
Unknown	U

- *Dace live in fast moving waters although can also be present in lowland lakes (Miller and Loates 1997) and estuaries (Caffrey et al. 2007).*
- *This species is present in the North, Baltic, White, and Barents Sea basins; the Volga and Ural drainages of the Caspian basin; from the Danube to Dniepr drainages in the Black Sea basin; the Seine drainage of the Atlantic basin; and the Mediterranean basin from the Rhône to the Arc drainages (France). It is also found in very localized populations in the main Danube River in Romania, as well as in Scandinavia north of 69°N, most of central Finland, and In Siberia eastwards to Kolyma drainage (Freyhof 2013).*
- *In Ireland, dace expansion has followed a similar but less rapid course as the invasion of roach (Caffrey et al. 2007).*
- *The eggs of* Leuciscus leuciscus *stick to substrates (Mills 1981), but it is unknown whether they would stick to transoceanic ship structures.*

Vector Potential Scorecard				
Vector	**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind	**0**	x	**0**	Unlikely
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.	**0**	x	**0**	Unlikely
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)	**0**	x	**0**	Unlikely
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)	**0**	x	**0**	Unlikely
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)	**0**	x	**0**	Unlikely
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling	**80**	x 0.5	**40**	Moderate
Total Unknowns (U)	**0**	**Confidence Level**	High	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

<u>ESTABLISHMENT POTENTIAL RESULTS</u>

Status: **Not established in North America, including the Great Lakes**

***Leuciscus leuciscus* has a moderate probability of establishment if introduced to the Great Lakes (Confidence level: High).**

Leuciscus leuciscus inhabits rivers and lakes (Caffrey et al. 2007) and is susceptible to habitat degradation (Copp et al. 2007). This species occurs in the upper Thames estuary, which has a salinity range of 0.34 – 2.96 p.s.u. and water temperatures of 2.5 – 20°C (Araújo et al. 1999); these ranges are salinity and temperature ranges are similar to those in the Great Lakes (Reid and Orlova 2002). In the upper Thames estuary, *Leuciscus leuciscus* is most common in Isleworth, which has an average dissolved oxygen saturation of about 100%. It may tolerate the cool waters during the winters in the Great Lakes, but its capacity to overwinter may be limited by the level of dissolved oxygen (Araújo et al. 1999, Leuven et al. 2011). Warmer water temperatures and shorter duration of ice cover may aid the establishment of *Leuciscus leuciscus*. This species is more abundant in warmer waters with lower flows, high dissolved oxygen, and low pH (Araújo et al. 1999); although it is found in fast flowing waters as well (Caffrey et al. 2007). Egg and larval survival is greater when the spring-fall season is warmer (Nunn et al. 2003). Relative fecundity of *Leuciscus leuciscus* is about 40 eggs g^{-1} (Helawell 1974), which is similar to the relative fecundity of *Leuciscus idus* that is 23.584 – 48.789 eggs g^{-1} (Targónska et al. 2012).

This species has a relatively broad diet that varies seasonally; thus it is likely to find a food source in the Great Lakes basin. The distribution of *Leuciscus leuciscus* sometimes overlaps with that of popular sport fish such as brown trout *Salmo trutta* L. and rainbow trout *Oncorhynchus mykiss* Walbaum, and some have suggested that *Leuciscus leuciscus* competes with these commercially important fish for food and habitat; however, its competitive abilities have yet to be studied (King et al. 2011, Mann and Mills 1986). Dace is invasive in Ireland, and is considered a potential threat to the brown trout (King et al. 2011) and salmonoids (Caffrey et al. 2007).

Leuciscus leuciscus was introduced to Munster Blackwater in Ireland in 1889 and did not spread until the early 1990s (Caffrey et al. 2007). In 1994, this species was first reported in the River Barrow and rapidly spread upstream.

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
	5

- *This species has the ability to osmoregulate (O'hara 1976).*
- *This species has been present in brackish estuaries of surveyed rivers, though is unable to travel to more saline waters closer to sea (Caffrey et al. 2007).*
- *This species is eurythermal, tolerating temperatures between 4-28˚C (Leuven et al. 2011) and pH from 6-8.*

- *This species occurs in the upper Thames estuary which has a salinity range of 0.34 – 2.96 p.s.u. and water temperatures of 2.5 – 20°C (Araújo et al. 1999). In the upper Thames estuary,* Leuciscus leuciscus *is most common in Isleworth, which has an average dissolved oxygen saturation of about 100%.*
- *This species is more abundant in warmer waters with lower flows, high dissolved oxygen, and low pH (Araújo et al. 1999); although it can also be found in fast flowing waters as well (Caffrey et al. 2007).*

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9
Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
	3

- *This species as an adult may be likely to survive overwintering (Hartley 1947) .*
- *This species may tolerate some of these conditions such as low temperature (Araújo et al. 1999, Leuven et al. 2011), but might not be able to tolerate low dissolved oxygen levels.*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
	8

- *This species has a highly variable omnivorous diet (Cowx 2001).*
- *In the summer Dace will feed on flying insects, while in the winter it may feed on detritus, plant content and mollusks (Helawell 1974, Mann 1974).*
- *This species feeds year round and its diet changes seasonally (Cowx 2001). Its feeding activity peaks in the summer. It has a highly varied omnivorous diet comprising of insects, algae, and detritus.*

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	6

Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	0
Unknown	U
	6

- *This species is often observed in large shoals that can reduce the amount of food available for other species (Kennedy 1969).*
- *This species primarily feeds on the same flying insects the young trout and salmon would during summer months (Weatherley 1987).*
- *This species spawns in the same habitats (graveled areas) as would trout and salmon (Caffrey et al. 2007).*
- *The distribution of* Leuciscus leuciscus *sometimes overlaps with that of popular sport fishes such as brown trout* Salmo trutta L. *and rainbow trout* Oncorhynchus mykiss Walbaum*, and some have suggested that* Leuciscus leuciscus *competes with these commercially important fish for food and habitat; however, the competitive ability of* Leuciscus leuciscus *has not been studied (Mann and Mills 1986).*
- *The Ireland Red List considers Dace one of the potential threats to brown trout populations (King et al. 2011).*

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
	7

- *Cowx (2001) estimated that the yearly fecundity of dace was 6,550 to 9,500 eggs per 20 cm female, while other estimates range for 1550 to 22600 eggs (Zhukov 1965, Movchan and Smirnow 1981).*
- *Wilkinson and Jones (1977) found average fecundity of around 80 eggs g^{-1}.*
- *Dace is reported as having high fecundity (King et al. 2011).*
- *Relative fecundity is reported to be about 40 eggs g^{-1} (Helawell 1974).*
- *Relative fecundity of similar species,* Leuciscus idus*, had average fecundities ranging from 23.584 eggs g^{-1} to 48.789 eggs g^{-1} (Targónska et al. 2012).*

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6

Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
	0

- *Within its native range, this species typically reproduces between February and March when the water temperature is at a minimum of 10˚C (Kennedy 1969).*

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	6

- *This species occurs in the upper Thames estuary, which has a salinity range of 0.34 – 2.96 p.s.u. and water temperatures of 2.5 – 20°C (Araújo et al. 1999), and the Baltic Sea, which has a salinity range of 1-15 ppt and water temperatures of 0 - 20°C; these ranges are salinity and temperature ranges are similar to those in the Great Lakes (Reid and Orlova 2002).*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	6

- *Dace is reported as being susceptible to pollution (Copp et al. 2007).*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0
Unknown	U
	8

- *This species typically lives in fast moving streams and rivers, though may be found in lowland lakes (Miller and Loates 1997).*
- *This species is abundant in warmer waters with lower flows, high dissolved oxygen, and low pH (Araújo et al. 1999).*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0
Unknown	U
	6

- *This species is more abundant in warmer waters (Araújo et al. 1999).*
- *Egg and larval survival is greater when the spring-fall season is warmer, and is positively correlated with the number of consecutive days > 12°C (Nunn et al. 2003).*
- *Low dissolved oxygen due to ice cover may limit the ability of this species to overwinter in the Great Lakes, so shorter duration of ice cover may aid its capacity to overwinter and its establishment.*

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is moderate to high)	3

Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
	9

- *In the summer dace will feed on flying insects, as do trout and salmon (Weatherley 1987), while in the winter it may feed on detritus and mollusks (Helawell 1974, Mann 1974).*

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

No, there is no critical species required by the species being assessed	9
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Great Lakes and is not likely to be introduced	-80% total points (at end)
Unknown	U
	9

- *No critical species is needed for any stage in Dace's life cycle.*

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes)	6
Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0
Unknown	U
	0

- *There is no species known to facilitate Dace's establishment.*

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0
Unknown	U
	0

- *This fish is preyed upon by the pike and its other piscivorous relatives, though for this reason it became introduced to Ireland while being used as a bait fish (Winfield et al. 2011).*

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9
Frequent, moderate inocula	6
Frequent, small inocula OR infrequent, large inocula	3
Infrequent, small or moderate inocula	0
Unknown	U
	U

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6

Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
	3

- *This species does have sustaining populations in Ireland which is not within its native habitat (Caffrey et al. 2007).*

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
	3

- *It took Dace over 100 years to spread beyond the Munster Blackwater after its introduction to Ireland; however, it took only 14 years for its subsequent spread though 70 km of river (Caffrey et al. 2007).*

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing the establishment and spread of this species)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent the establishment and/or spread of this species	0
Unknown	U
	0

- *Physical barriers (e.g., dams) and rotenone treatment are used to control small fish (CABI.org), and may help in preventing the spread of this species if introduced (CABI.org).*

Establishment Potential Scorecard				
Points	**Probability for Establishment**	A. Total Points (pre-adjustment)		79
>100	High	**Adjustments**		
		B. Critical species	A*(1- 0%)	79
51-99	Moderate	C. Natural enemy	B*(1- 0%)	79
		Control measures	C*(1- 0%)	79
0-50	Low	**Potential for Establishment**		Moderate
# of questions answered as "unable to determine"	**Confidence Level**			
0-1	High	Total # of questions unknown		1
2-5	Moderate			
6-9	Low	Confidence Level		High
>9	Very low			

Section C: Potential for Impact

IMPACT POTENTIAL RESULTS

Environmental: High

Socio-Economic: High

Beneficial: Moderate

***Leuciscus leuciscus* has the potential for high environmental impact if introduced to the Great Lakes.**

Leuciscus leuciscus is suspected to compete with salmonoids for breeding habitat (Caffrey et al. 2007). Efforts conserve salmonoid populations in Ireland have been hampered by *Leuciscus leuciscus*. *Leuciscus leuciscus* were reported to use breeding grounds intended for salmon breeding, thereby reducing the availability of breeding grounds for salmon. It has been suggested by Caffrey et al. (2007) and King et al. (2011) that if *Leuciscus leuciscus* reaches high abundances, it may compete with brown trout and other native fish of Ireland for food; however, the level of competition for food and its effects on native populations has not been studied in-depth. It has been reported that *Leuciscus leuciscus* can hybridize with chub (*Leuciscus cephalus* L.) and bleak (*Alburnus alburnus* L.) (Bourgeois 1963, Kennedy and McCarthy 1965); however, these fish do not occur in the Great Lakes and are native to Europe. *Leuciscus leuciscus* is not known to impact water quality of the physical components of ecosystems.

***Leuciscus leuciscus* has the potential for high socioeconomic impact if introduced to the Great Lakes.**

Leuciscus leuciscus is not a threat to human health or water quality. It does not damage infrastructure. It has not been reported that this species negatively affects markets or economic sectors. It does not diminish the aesthetic or natural value of the area it inhabits.

Leuciscus leuciscus can reach very high densities and resides in shoals. For coarse (non-game) anglers, the high abundance of dace is beneficial (Caffrey et al. 2007). For game anglers, the high abundance of dace is a nuisance because these fish often take the lure casts intended for catching trout. The breeding grounds created for salmon conservation are used by dace, limiting the availability of breeding grounds for the salmon and hindering salmon conservation.

***Leuciscus leuciscus* has the potential for moderate beneficial impact if introduced to the Great Lakes.**

In Ireland, *Leuciscus leuciscus* has become an important angling species after spreading throughout the River Barrow (Caffrey et al. 2007). *Leuciscus leuciscus* was accidently released into Irish rivers while being used as live bait. This species has the potential to be used as live bait and used for recreational coarse fishing.

POTENTIAL ENVIRONMENTAL IMPACT

NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1
Not significantly	0
Unknown	U √

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6 √
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1
Not significantly	0
Unknown	U

- *When in large numbers Dace can significantly reduce the amount of available food (Kennedy and McCarthy 1965).*
- *The biggest impact Dace has had on invaded systems is the impact is has on native salmonids. They occupy the same habitats and have significantly similar feeding habits (Caffrey et al. 2007). Efforts to conserve salmonoids*

by creating suitable breeding grounds have been hampered. Dace used these breeding grounds intended for salmon breeding which reduced the amount of available breeding grounds for salmon.

- *Efforts to increase breeding habitat for salmonids in Ireland have been intruded upon by the Dace (Caffrey et al. 2007).*

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in the food web)	6
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	1
Not significantly	0
Unknown	U √

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1 √
Not significantly	0
Unknown	U

- *It has been known to hybridize with other species in its natural range, or with those same species in systems that have been invaded by both species (Costedoat et al. 2006).*
- *It has been reported that* Leuciscus leuciscus *can hybridize with Chub (*Leuciscus cephalus L.*) and Bleak (*Alburnus alburnus L.*) (Bourgeois 1963, Kennedy and McCarthy 1965).*

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1
Not significantly	0
Unknown	U √

E6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1
Not significantly	0 √
Unknown	U

- *This species feeds on various types of plants depending on the season and food availability (Caffrey et al. 2007), yet there is no mention of it altering these communities.*

Environmental Impact Total	**7**
Total Unknowns (U)	**3**

Scoring		
Score	# U	**Impact**
>5	Any	**<u>High</u>**
2-5	Any	Moderate
0	0-1	Low
1	0	
0	≥2	Unknown
1	≥1	

<u>POTENTIAL SOCIO-ECONOMIC IMPACT</u>

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1
Not significantly	0 √
Unknown	U

S2) Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1
Not significantly	0 √
Unknown	U

S3) Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0 √
Unknown	U

S4) Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6 √
Yes, but negative consequences have been small	1
Not significantly	0
Unknown	U

- *This species can reach very high abundances and resides in shoals. For coarse (non-game) anglers, the high abundance of dace is beneficial (Caffrey et al. 2007). For game anglers, the high abundance of dace is a nuisance because they often take the lure casts intended for catching trout.*
- *The breeding grounds created for salmon conservation are used by dace, limiting the availability of breeding grounds for the salmon and hindering salmon conservation (Caffrey et al. 2007)*

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6
Yes, but negative consequences have been small	1

Not significantly	0 √
Unknown	U

Socio-Economic Impact Total	**6**
Total Unknowns (U)	**0**

Scoring		
Score	# U	**Impact**
>5	Any	**<u>High</u>**
2-5	Any	Moderate
0	0-1	Low
1	0	
0	≥2	Unknown
1	≥1	

POTENTIAL BENEFICIAL EFFECT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular effect. An "Unknown" response is appropriate if the potential for a particular effect might be inferred but has not been explicitly reported or if there is an unresolved debate about a particular effect.

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1
Not significantly	0 √
Unknown	U

- *Commonly feeds on mollusks depending on season and food availability (Caffrey et al. 2007, Helawell 1974, Mann 1974), though little information is provided on the types of mollusks consumed by the Dace.*

B2) Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?

Yes, it is economically important to at least one of these industries	6
Yes, but its economic contribution is small	1 √
Not significantly	0
Unknown	U

- *This species is consumed by fisherman, and sometimes seen in canned form.*
- *This species was introduced to Ireland after accidental release of live bait (Caffrey et al. 2007).*

B3) Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local communities and/or tourism	6
It is sometimes employed recreationally, but adds little value to local communities or tourism	1 √
Not significantly	0
Unknown	U

- *This species can reach high abundances. This species is used in Ireland for coarse angling (Caffrey et al. 2007).*

B4) Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR It is potentially important to medicine or research and is currently being or scheduled to be studied	1
Not significantly	0 √
Unknown	U

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1
Not significantly	0 √
Unknown	U

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1
Not significantly	0 √
Unknown	U

Beneficial Effect Total	**2**

Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	**Moderate**
0	0-1	Low
1	0	
0	≥2	Unknown
1	≥1	

Scientific Name: *Neogobius fluviatilis*
Pallas, 1814

Common Name: Monkey Goby, Sand Goby, River Goby

Synonyms:

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: Unlikely

Hitchhiking/fouling: Unlikely

Unauthorized intentional release: Unlikely

Stocking/planting/escape from recreational culture: Unlikely

Escape from commercial culture: Unlikely

Transoceanic shipping: Moderate

***Neogobius fluviatilis* has a moderate probability of introduction to the Great Lakes (Confidence level: High).**

Potential pathway(s) of introduction: Transoceanic Shipping (ballast water)

Neogobius fluviatilis is predicted to be introduced to the Great Lakes via ballast water (Holeck et al. 2004, Kolar and Lodge 2002, Ricciardi and Rasmussen 1998). *Neogobius fluviatilis* is euryhaline and can tolerate a broad range of temperature, so it may be able to survive ballast tank environments. It has been found in waters with temperatures of 0-32.4°C (Biró 1997, Sasi and Berber 2010), and salinities between 0-10 ppt (Lejk et al. 2013, Plotnikov et al. 2012). This species occurs in waters from which shipping traffic to the Great Lakes originates (NBIC), including the Baltic Sea (Lejk et al. 2013). *Neogobius fluviatilis* occurs in the River Vistula catchment, which is part of the Baltic Sea basin (Copp et al. 2005). *Neogobius fluviatilis* may be introduced to the Great Lakes via ships declaring "No Ballast on Board" (NOBOB), which are exempt from ballast water exchange. Holeck et al. (2004) specifically states this introduction will be through BOB water or NOBOB residual water. The majority of ships entering the Great Lakes are NOBOB vessels and 43% of these ships contain residual water with less than 10% salinity (Johengen et al. 2005). Temperature of the residual water from the vessels sampled ranged from -0.7 to 23.9°C; thus *Neogobius fluviatilis* is likely to survive the salinity and temperature of the NOBOB ballast water (Johengen et al. 2005).

Neogobius fluviatilis does not occur near waters connected to the Great Lakes basin. This species is not known to adhere to any surfaces or be transported by other organisms. *Neogobius fluviatilis* is not stocked, cultured, or sold in the Great Lakes region.

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100
No, this species does not occur near waters connected to the Great Lakes basin and/or is not mobile or able to be transported by wind or water.	0 √
Unknown	U

- *The Monkey Goby,* Neogobius fluviatilis*, occurs throughout southeastern Europe, including the Black Sea, Sea of Azov, and Caspian Sea and all included tributaries (Whitehead et al. 1986). It has been invading these tributaries and moving towards Western Europe as far Hungary and Poland (Biró 1972, Copp et al. 1986, Whitehead et al. 1986).*

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0 √
Unknown	U

- Neogobius fluviatilis *is not known to adhere to any surfaces or be transported by other organisms. There is no record of this form of transport, but there are mentions of aquaculture and likely ballast transport (Holeck et al. 2004, Kolar and Lodge 2002).*

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1

Unknown	U

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a) Is this species sold at aquarium/pet/garden stores ("brick & mortar" or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100
No, this species this species is rarely/never sold.	0 √
Unknown	U

- Neogobius fluviatilis *is not known to be sold at any stores or supply companies. There is no record of this form of transport, but there are mentions of aquaculture and likely ballast transport (Holeck et al. 2004, Kolar and Lodge 2002).*

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0 √
Unknown	U

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is likely to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal	Score x 0.25

or state regulations in more than half the basin (> 5 states/provinces), this activity may occur within 20 km of the basin because of the species' popularity/value.	
Unknown	U

- *Kolar and Lodge (2002) state that the Monkey Goby is currently in water garden or aquarium trade in Europe and could potentially be transported to the Great Lakes as part of this trade.*

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100
No, this species is not commercially cultured in or transported through the Great Lakes region.	0 √
Unknown	U

- *The Monkey Goby is not known to be commercially cultured or transported through the Great Lakes region. There is no record of this form of transport, but there are mentions of aquaculture and likely ballast transport (Holeck et al. 2004, Kolar and Lodge 2002).*

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80 √
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40

No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0
Unknown	U

- *Multiple papers have predicted the probability of* N. fluviatilis *being introduced through ballast water (Copp et al. 2005, Holeck et al. 2004, Kolar and Lodge 2002, USEPA 2008). Holeck et al. (2004) specifically states that it could survive in BOB water or NOBOB residual water.*
- Neogobius fluviatilis *is known to be euryhaline and occupy brackish water. It also occupies a broad range of temperature that could aid in survival in ballast water (Kottelat and Freyhof 2007, Whitehead et al. 1986).*
- *A similar very invasive species,* Neogobius melanostomus*, is thought to have spread to the Great Lakes through ballast water. These species are rather similar in tolerances and natural ranges, further supporting this transport vector (Kornis et al. 2012).*
- Neogobius fluviatilis *was introduced to parts of the Aral Sea in the mid-1950s and currently occurs there (Plotnikov et al. 2012). The Aral Sea is a brackish water body and has an average salinity of 10 ppt.(Plotnikov et al. 2012).*

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5 √
Yes, but this species has neither been observed in ballast/fouling ships entering the Great Lakes nor in ports in direct trade with the Great Lakes.	Score x 0.1
No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0
Unknown	U

- Neogobius fluviatilis *has spread throughout much of Europe, pushing farther and farther northwest from its native range. This has been no direct observation in the Baltic Sea as of 2005, but it has been found in the basin and predicted to reach the sea (Copp et al. 2005).*
- *This species was introduced to Polish inland waters during the mid-1990s and has spread to the southern Baltic Sea (Lejk et al. 2013).*

Vector Potential Scorecard				
Vector	**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind	**0**	x	**0**	Unlikely
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.	**0**	x	**0**	Unlikely
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)	**0**	x	**0**	Unlikely
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)	**0**	x	**0**	Unlikely
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)	**0**	x	**0**	Unlikely
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling	**80**	x 0.5	**40**	Moderate
Total Unknowns (U)	**0**	**Confidence Level**	High	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

ESTABLISHMENT POTENTIAL RESULTS

Status: Not established in North America, including the Great Lakes

***Neogobius fluviatilis* has a high probability of establishment if introduced to the Great Lakes (Confidence level: High).**

The native and introduced ranges of *Neogobius fluviatilis* have similar climatic and abiotic conditions as the Great Lakes (Grigorovich et al. 2003, Reid and Orlova 2002, USEPA 2008). *Neogobius fluviatilis* has not been shown to have specific habitat preferences in laboratory experiments (van Kessel et al. 2011). In the experiments, this species was frequently observed choosing a variety of habitat types including shelter, vegetation, large gravel, sand, and mixtures of gravel and sand (van Kessel et al. 2011). In the Danube River in Slovakia, *Neogobius fluviatilis* were predominantly found in stretches with gravel or rocky substrates (Jurajda et al. 2005). Genetic Algorithm for Rule-Set Production (GARP) model predicts that shallower waters of the Great Lakes provide suitable habitats for *Neogobius fluviatilis*, including parts of Lake Huron, Lake Michigan, Lake Erie, and Lake Ontario (USEPA 2008). *Neogobius fluviatilis* has a broad temperature tolerance; it inhabits waters that freeze in the winter (Biró 1997), as well as waters with temperatures up to 32.4°C (Sasi and Berber 2010). *Neogobius fluviatilis* can tolerate fresh to brackish waters with salinities of 0-10 ppt (Lejk et al. 2013, Plotnikov et al. 2012). *Neogobius fluviatilis* occurs in waters that have ice cover in the winter, such as Lake Balaton (Biró 1997), so it is likely to be capable of overwintering in the Great Lakes. Lake Balaton's water quality was impacted by eutrophication in the 1960s, yet this species was able to establish there in the early 1970s (Biró 1997); thus nutrient levels of the Great Lakes will not likely affect the establishment of *Neogobius fluviatilis*. Due to its tolerance of a wide range of water temperatures and salinity, the effects of climate change in the Great Lakes may not affect the establishment of *Neogobius fluviatilis*.

This species has a diverse diet of macroinvertebrates, crustaceans, gastropods, and fish (Grabowska et al. 2009); thus it is likely to find an appropriate food source in the Great Lakes basin. In laboratory experiments investigating habitat competition between native and invasive species, *Neogobius fluviatilis* did not significantly alter the habitat use of the native species *Cottus perifretum* or *Barbatula barbatula* (van Kessel et al. 2011). Depending on the size of the female, fecundity ranges from 300-2000 mature oocytes (Pinchuk et al. 2003). *Neogobius gymnotrachelus* has a fecundity of 361-2236 eggs (Grabowska 2005), which is greater than the fecundity of *N. fluviatilis*. Newly established populations of *Neogobius fluviatilis* may allocate more resources to reproduction, and live longer than *N. fluviatilis* populations in their native range (Plachá et al. 2010). It exhibits parental care and has an extended spawning period, which may contribute to reproductive success.

Kolar and Lodge (2002) predict that *Neogobius fluviatilis* will spread quickly if introduced to the Great Lakes. In the last 3 decades of the 20th century, this species was among 4 Ponto-Caspian gobies that expanded their range up the Volga River (Copp et al. 2005). This species is capable of upstream migration, and has expanded its range from the Djerdap Gorge in Serbia to the middle sections of the Danube River in Slovakia (Jurajda et al. 2005). The invasion history of *Neogobius fluviatilis* is characterized by range expansions occurring Eastern towards Western Europe. Within 7 years, it spread 836 km downstream from the Bug River to the mouth of the Vistula River (Kostrzewa and Grabowski 2002). After its introduction to the Aral Sea in the mid-1950s, *Neogobius fluviatilis* naturalized and its abundance grew quickly (Plotnikov et al. 2012). By the mid-1960s, *Neogobius fluviatilis* as well as other undesirable introduced goby species coincided with a significant reduction in the abundance of benthic invertebrates (Markova 1972, Plotnikov et al. 2012, Yablonskaya et al. 1973); however, it is unknown if *Neogobius fluviatilis* was responsible for the decline of benthic invertebrates.

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
	7

- Neogobius fluviatilis *is a benthic fish that occurs in temperate waters ranging from fresh to brackish and from 4°C - 20°C. It naturally occurs in the shallow regions of the Black Sea, Sea of Azov, and Caspian Sea and also within the tributaries of rivers.* Neogobius fluviatilis *spawns once water temperature reaches 13°C (Whitehead et al. 1986, Kottelat and Freyhof 2007).*
- Neogobius fluviatilis *is found in Manyas Lake, Turkey which has water temperatures of 8.80-32.40°C and dissolved oxygen levels of 6.10-10.90 mg/L (Sasi and Berber 2010).*
- *It has been found in waters with temperatures of 0-32.40°C (Biró 1997, Sasi and Berber 2010), and salinities between 0-10 ppt (Lejk et al. 2013, Plotnikov et al. 2012).*
- *This species is found in Manyas Lake, Turkey which has dissolved oxygen levels of 6.10-10.90 mg/L (Sasi and Berber 2010).*

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9
Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
	9

- Neogobius fluviatilis *is a benthic dwelling goby meaning that it occurs naturally in a lower oxygen environment. It is recorded as surviving in temperatures as low as 4°C within its natural range (Whitehead et al. 1986, Kottelat and Freyhof 2007).*
- Neogobius fluviatilis *mainly appears in littoral zones of lakes and rivers with low oxygen levels in Hungary (Keresztessy 1996).*
- *A very similar species that has invaded the Great Lakes,* Neogobius melanstomus*, occurs in the same natural range and has extremely similar physiological tolerances (Whitehead et al. 1986, Kottelat and Freyhof 2007).*
- *This species occurs in Lake Balaton, Hungary, which has ice cover from December to February (Biró 1997), so it is likely that it can overwinter in the Great Lakes.*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
	9

- Neogobius fluviatilis *is a generalist that feeds upon multiple benthic dwelling organisms. Included in its diet are crustaceans (especially corophiid amphipods), polychaetes, bivalves, small fish, and chironomid larvae (Whitehead et al. 1986, Kottelat and Freyhof 2007).*
- *Recent studies on diet and feeding strategies have confirmed that* N. fluviatilis *has a broad feeding spectrum (Grabowska et al. 2009, Abdoli et al. 2012).Its diet consists of macroinvertebrates, crustaceans, annelids, gastropods, and fishes, and is dominated by chironomid larvae (Grabowska et al. 2009).*

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	0
Unknown	U
	3

- Neogobius fluviatilis *has been found to have average competitive abilities. In a study concerning habitat selection,* N. fluviatilis *did not significantly affect native goby populations (van Kessel et al. 2011).*

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
	4

- Neogobius fluviatilis *has a lower fecundity rate when compared with other invasive gobies such as* N. melanostomus. Neogobius fluviatilis *reaches sexual maturity at age 2 and generally spawns from May throughout September. Females can spawn more than once in a season but not as often as other gobies. This is partially due to a greater parental investment in protecting eggs until they hatch (Kottelat and Freyhof 2007, Plachá et al. 2010, Whitehead et al. 1986).*
- *In a study on an invasive population of* N. fluviatilis*, it was found that they exhibited higher reproductive rates than native populations, but still lower fecundity than other invasive gobies (Plachá et al. 2010).*
- *Depending on the size of the female, fecundity ranges from 300-2000 mature oocytes (Pinchuk et al. 2003).* Neogobius gymnotrachelus *has a fecundity of 361-2236 eggs (Grabowska 2005), which is greater than the fecundity of* Neogobius fluviatilis.

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
	3

- *There are a few reproductive strategies that would likely assist* N. fluviatilis *in establishing. They are one of the few goby species in which the male takes care of the eggs until hatching. Furthermore, males grow larger and live longer. Some non-native populations have been found to live longer than native populations, which would allow more chances for spawning, and possibly increase invasion potential (Plachá et al. 2010).*

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- Neogobius fluviatilis *has been predicted to be very environmentally compatible with all five Great Lakes, at least in the shallower regions. Being closely related to* N. melanostomus*, which has successfully invaded all five Great Lakes, supports this prediction (USEPA 2008).*
- *In its native range* Neogobius fluviatilis *inhabits brackish lagoons of the Black Sea, Azov Sea, and Caspian Sea (Grabowska et al. 2009).*
- *The Ponto-Caspian (Caspian, Azov, and Black Seas) have similar climate and surface water temperature ranges as the Great Lakes (Grigorovich et al. 2003, Reid and Orlova 2002, USEPA 2008).*
- *The Great Lakes and Ponto-Caspian region are "climatically compatible," which is one of the attributing factors to the success of Ponto-Caspian species in the Great Lakes (Reid and Orlova 2002).*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- Neogobius fluviatilis *has been predicted to be very environmentally compatible with all five Great Lakes, at least in the shallower regions. Being closely related to* N. melanostomus*, which has very successfully invaded all five Great Lakes, supports this prediction (USEPA 2008).*
- *Great Lakes underwent similar anthropogenic eutrophication as the Ponto-Caspian region (Reid and Orlova 2002). Surface water temperature is similar between the Great Lakes and Ponto-Caspian seas (Grigorovich et al. 2003, Reid and Orlova 2002, USEPA 2008).*
- Neogobius fluviatilis *successfully established in Lake Balaton, Hungary in the early 1970s (Biró 1997). This lake experienced severe eutrophication in the 1960s.*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0
Unknown	U
	9

- *Predictions made by USEPA (2008) show that most of Lake Erie, and parts of Lake Huron and Lake Ontario will be suitable habitat for* N. fluviatilis. *Being closely related to* N. melanostomus*, which has successfully invaded all five Great Lakes, supports this prediction (USEPA 2008).*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0
Unknown	U
	9

- Neogobius fluviatilis, *due to its wide range of tolerances, would adapt easily to warmer water temperatures and possibly increased salinization (Kottelat and Freyhof 2007, Whitehead et al. 1986).*
- *It has been found in waters with temperatures of 0-32.40°C (Biró 1997, Sasi and Berber 2010), and salinities between 0-10 ppt (Lejk et al. 2013, Plotnikov et al. 2012).*

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
	9

- Neogobius fluviatilis *feeds upon a wide range of benthic macroinvertebrates (Kottelat and Freyhof 2007, Whitehead et al. 1986), including bivalves such as the invasive zebra and quagga mussels (Kipp et al. 2012).*
- Neogobius fluviatilis *has an extremely similar diet to* N. melanostomus *which has spread across North America with no dietary constraints (Kipp et al. 2012).*

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being assessed;	9

OR, No, there is no critical species required by the species being assessed	
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Great Lakes and is not likely to be introduced	-80% total points (at end)
Unknown	U
	9

- *The only reproductive requirement* N. fluviatilis *has is small stones and aquatic plants to which to attach its eggs. There are no otherwise required species in its life cycle (Kottelat and Freyhof 2007, Whitehead et al. 1986).*

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes)	6
Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0
Unknown	U
	1

- *There is no species that aids the establishment and spread of* N. fluviatilis*, although the presence of dreissenid mussels may help to support its diet*. Neogobius melanostomus, *A related species is known to predateom dreissend mussels in the Great lakes absin (Hogan et al. 2007).*

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well	-80% total points (at

documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0
Unknown	U
	0

- Neogobius fluviatilis *has spread across Europe with no recorded preferential predation or prevention of spread occurring. There are reports of predation by native pikeperch, but they only target* N. fluviatilis *at certain size classes (Specziár 2011).*
- Neogobius fluviatilis *can become slightly larger than other similar gobies and benthic dwelling fish, possibly making it a preferred target for larger piscivores, but there are no records of this (Kottelat and Freyhof 2007, Whitehead et al. 1986).*

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9
Frequent, moderate inocula	6
Frequent, small inocula OR infrequent, large inocula	3
Infrequent, small or moderate inocula	0
Unknown	U
	U

- *There is no record of* N. fluviatilis *actually being transported by ballast water or through live trade. There have been multiple predictions that this vector will lead to its introduction, but as there are no actual cases, it is assumed that inoculations are very low (Kolar and Lodge 2002, Holeck et al. 2004).*

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6

Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
	6

- Neogobius fluviatilis *has spread from its native range of the Black and Caspian Seas to the Baltic Sea basin, Aral Sea, and throughout western and eastern Europe (Copp et al. 2005).*
- *It is capable of upstream migration (Jurajda et al. 2005).*
- *This species can be found from the Ponto-Caspian to Hungary (Ahnelt et al. 1998), Slovakia (Jurajda et al. 2005), Poland (Tockner et al. 2009), and the Netherlands (van Kessel et al. 2009). It has historically spread from east to west.*

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
	7

- *There are documented geographical ranges of* N. fluviatilis *reported from the early 1970s (Biró 1972). Recent studies show that this range has increased extensively, almost doubling in roughly 30 years (Copp et al. 2005, Kottelat and Freyhof 2007, Whitehead et al. 1986).*
- *A primary cause of this spread is human activities, such as connecting rivers and international shipping (Copp et al. 2005, Kornis et al. 2012).*
- *It was found in the Bug River in Poland in 1997, and within 7 years it expanded 836 km to the mouth of the river (Kostrzewa and Grabowski 2002).*
- *After its introduction to the Aral Sea in the mid-1950s,* Neogobius fluviatilis *naturalized and its abundance grew quickly (Plotnikov et al. 2012).*
- *Kolar and Lodge (2002) predict that* Neogobius fluviatilis *will spread quickly if introduced to the Great Lakes.*
- *Over the past few decades, it has extended its range to include the Slovakian section of the Danube (Jurujda et al. 2005).*
- *In the last 3 decades of the 20th century, this species was among 4 Ponto-Caspian gobies that expanded their range up the Volga River (Copp et al. 2005).*
- *Within 7 years, it spread 836 km downstream from the Bug River to the mouth of the Vistula River (Kostrzewa and Grabowski 2002).*

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are	-90% total points (at

highly effective in preventing the establishment and spread of this species)	end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent the establishment and/or spread of this species	0
Unknown	U
	0

- *Rotenone is one possibly control measure that could be used to control the establishment/spread of* N. fluviatilis*. It is a chemical measure that is mainly used to protect fisheries and only has a few other realistic applications. It would likely not be a realistic control measure (Abdel-Fattah 2011).*

Establishment Potential Scorecard				
Points	**Probability for Establishment**	A. Total Points (pre-adjustment)		101
>100	High	**Adjustments**		
		B. Critical species	A*(1- 0%)	101
51-99	Moderate	C. Natural enemy	B*(1- 0%)	101
		Control measures	C*(1- 0%)	101
0-50	Low	**Potential for Establishment**		High
# of questions answered as "unable to determine"	**Confidence Level**			
0-1	High	Total # of questions unknown		1
2-5	Moderate			
6-9	Low	Confidence Level		High
>9	Very low			

Section C: Potential for Impact

<u>IMPACT POTENTIAL RESULTS</u>

Environmental: Moderate

Socio-Economic: Low

Beneficial: Moderate

***Neogobius fluviatilis* has the potential for moderate environmental impact if introduced to the Great Lakes.**

Neogobius fluviatilis is known to be the carrier of some species of parasites, and, it had the greatest parasite diversity and the lowest parasite abundance compared to 2 other non-native goby species found in the Danube River (Ondračková et al. 2005). None of the parasites were brought to the Danube by the introduction of *Neogobius* fishes; rather, they were common in the Danube. The parasite loads in *Neogobius fluviatilis* in the Danube River were similar to the parasite loads in their native range. Parasites of *Neogobius fluviatilis* in the Danube River include trematoda *Nicolla skrjabini* (Iwanitzky, 1928), *Metagonimus yokogawai* (Katsurada, 1912), *Apatemon cobitidis* (Linstow, 1980), *Pomphorhynchus laevis* (Müller, 1776), *Raphidascaris acus* (Bloch, 1779), ciliophora *Ichthyophthirius multifiliis* (Fouquet, 1876), *Eimeria daviesae* (Molnár, 2000), and *Goussia kessleri* (Molnár, 2000) (Molnár 2006). Specimens of *Neogobius fluviatilis* in the Vistula River were infected with the metacercariae of *Bucephalus polymorphus*, a parasite that also infects zebra mussels (Kvach and Mierzejewska 2011). The effects of the parasites infecting *Neogobius fluviatilis* on zebra mussels have not been reported.

Where introduced, *Neogobius fluviatilis* may potentially impact native fish populations. A marked decline in tubenose goby in the Danube River was attributed to the rapid expansion of round goby and monkey goby populations in 2004 (Molnár 2006). Experiments investigating habitat competition between non-native and native fish of the Rhine and Meuse rivers did not find that native fish *Cottus perifretum* or *Barbatula barbatula* changed their selection of habitat type when they co-occurred with *Neogobius fluviatilis*. These experiments suggest that *Neogobius fluviatilis* does not compete with native benthic fish for habitat, but its competitive behavior may change during spawning season (van Kessel et al. 2011).

Neogobius fluviatilis makes up a substantial proportion of the diets of piscivorous fish such as *Sander lucioperca* and *S. volgensis* in Lake Balaton (Specziár 2011). The effects of non-native prey on the diets of *S. lucioperca* and *S. volgensis* or on predator-prey relationships has not been explored. The expansion of *Neogobius fluviatilis* as well as other undesirable introduced goby species coincided with a significant reduction in the abundance of benthic invertebrates (Markova 1972, Plotnikov et al. 2012, Yablonskaya et al. 1973); however, it is unknown if *Neogobius fluviatilis* was responsible for the decline of benthic invertebrates.

There is little or no evidence to support that *Neogobius fluviatlis* has the potential for significant socio-economic impacts if introduced to the Great Lakes.

It has not been reported that *Neogobius fluviatilis* poses a threat to human health or water quality. There is no evidence that this species negatively impacts infrastructure, economic sectors, recreational activities and associated tourism, or the aesthetic appeal of the areas it inhabits.

***Neogobius fluviatilis* has the potential for moderate beneficial impact if introduced to the Great Lakes.**

In Turkey, *Neogobius fluviatilis* is important to minor commercial fisheries, aquarium, and bait (Sasi and Berber 2010). They may serve as a source of food for economically important fish species such as pike-perch *Stizostedion lucioperca* (Lenhardt et al. 2011).

POTENTIAL ENVIRONMENTAL IMPACT

NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1 √
Not significantly	0
Unknown	U

- Neogobius fluviatilis*, like other gobiids, is known to be the carrier of a large number of parasites. During a survey of* Neogobius *species that had recently invaded Hungarian reaches of the Danube River upstream from Budapest, it was found that Monkey Gobies introduced parasites of a wide host range, such as the trematode* Nicolla skrjabini*, the metacercariae of* Metagonimus yokogawai *and* Apatemon cobitidis*, the larval stages of the acanthocephalan* Pomphorhynchus laevis *and the nematode* Rhaphidascaris acus*, the glochidia of an* Anodonta *sp. (Mollusca), and the ciliophoran* Ichthyophthirius multifiliis*. The specific parasites of* Neogobius *spp. were represented by three intestinal coccidia:* Eimeria daviesae*,* Goussia kessleri*, and a new species described here as* Goussia szekelyi *sp. (Molnár 2006).*
- *Kornis et al. (2012) mentioned a loose connection between trematodes infecting* N. melanostomus *being passed onto double-crested cormorants* Phalacrocorax auritus.
- Neogobius fluviatilis *was found to be an intermediate host of* Bucephalus polymorphus *which can affect* Dreissenia polymorpha *and fish that feed on these two intermediate hosts (Kvach and Mierzejewska 2011).*

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1 √
Not significantly	0
Unknown	U

- Neogobius fluvialitis *is a potential competitor with benthic fish species native to its introduced ranges in Central Europe. Monkey Gobies have overlapping diets with benthic species native to Europe such as* Blicca Bjoerkna *(Freyhof and Kottelat 2008b, van Kessel et al. 2011). However, according to the results of these studies, interspecific competition might not be a strong factor because of dissimilarities in spatial foraging and shelter preferences among these species. van Kessel and others (2011) noted that due to the relatively small size of the gobiids used in their experiment, competition forces might have been downplayed. Another study carried out in the Hungarian reaches of the Danube found that previously widespread* Proterorhinus marmoratus *populations were drastically reduced in the presence of* N. melanostomus *and* N. fluviatilis *(Molnár 2006).*
- *A study of invasive gobies in the lower Rhine found that* N. fluviatilis *is extremely opportunistic and did not outcompete other invasive goby species but rather exploited resources that were not in use (Borcherding et al. 2013)*

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in the food web)	6
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	1 √
Not significantly	0
Unknown	U

A study done on native Pike-perch showed that N. fluviatilis *can be an important prey species during ontogeny, reducing the predation pressure placed on other native prey fish (Specziár 2011). This has the potential to result in a trophic cascade.*

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0 √
Unknown	U

- *There is no record of a genetic effect on native populations.*

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1
Not significantly	0 √
Unknown	U

- *There is no record of an effect on water quality.*

E6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6

Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1
Not significantly	0 √
Unknown	U

- *There is no reported effect on other physical components of the ecosystem.*

Environmental Impact Total	**3**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	**Moderate**
0	0-1	Low
1	0	
0	≥2	Unknown
1	≥1	

POTENTIAL SOCIO-ECONOMIC IMPACT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1
Not significantly	0 √
Unknown	U

- Neogobius fluviatilis *carries multiple parasites that affect fish and invertebrates but none that pose any threat to human health (Molnár 2006).*

S2) Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1

Not significantly	0 √
Unknown	U

- Neogobius fluviatilis *does not cause damage to infrastructure.*

S3) Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0 √
Unknown	U

- Neogobius fluviatilis *does not negatively affect water quality.*

S4) Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

- Neogobius fluviatilis *does not negatively affect any economic sectors.*

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

- Neogobius fluviatilis *does not negatively affect recreational activities.*

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

- Neogobius fluviatilis *does not negatively affect the natural value of invaded areas.*

Socio-Economic Impact Total	**0**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**Low**
1	0	
0	≥2	Unknown
1	≥1	

POTENTIAL BENEFICIAL EFFECT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular effect. An "Unknown" response is appropriate if the potential for a particular effect might be inferred but has not been explicitly reported or if there is an unresolved debate about a particular effect.

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1
Not significantly	0 √
Unknown	U

- Neogobius fluviatilis *does not act as a biological control.*

B2) Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?

Yes, it is economically important to at least one of these industries	6
Yes, but its economic contribution is small	1 √
Not significantly	0
Unknown	U

- *The Monkey Goby does not seem to have a significant economic or commercial value, besides its importance for minor commercial fisheries, aquariums, and bait (Sasi and Berber 2010). However, this species may serve as favorable food for economically important fish species (Catfish* Silurus glanis*, Pike-perch* Stizostedion lucioperca*). The increase in the commercial catch of Pike-perch in the last few years in Serbia has been likely due in part to an increase in the amount of gobiids found in the food consumed by Pike-perch (Lenhardt et al. 2011).*

B3) Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local communities and/or tourism	6
It is sometimes employed recreationally, but adds little value to local communities or tourism	1 √
Not significantly	0
Unknown	U

- *Anglers use this species as good bait for catfish and pike-perch (Lenhardt et al. 2011).*

B4) Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR It is potentially important to medicine or research and is currently being or scheduled to be studied	1
Not significantly	0 √
Unknown	U

- Neogobius fluviatilis *does not have any medicinal or research value.*

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1
Not significantly	0 √
Unknown	U

- Neogobius fluviatilis *does not improve water quality.*

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1
Not significantly	0 √
Unknown	U

- *This species does not have another positive ecological effect.*

Beneficial Effect Total	**2**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	**Moderate**
0	0-1	Low
1	0	
0	≥2	Unknown
1	≥1	

Scientific Name: *Oncorhynchus keta*
Walbaum, 1792

Common Name: Chum Salmon

Synonyms:

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: Unlikely

Hitchhiking/fouling: Unlikely

Unauthorized intentional release: Unlikely

Stocking/planting/escape from recreational culture: Unlikely

Escape from commercial culture: Unlikely

Transoceanic shipping: Unlikely

***Oncorhynchus keta* has a low probability of introduction to the Great Lakes (Confidence level: High).**

Potential pathway(s) of introduction: None

Oncorhynchus keta was introduced to the Great Lakes region by American and Canadian agencies in order to develop a self-sustaining, wild population to contribute to food, commercial, and recreational fisheries (Crawford 2001). From 1908 to the 1940s, *Oncorhynchus keta* were raised in hatcheries in Michigan, Pennsylvania, and Wisconsin, for release into Lakes Superior and Lake Huron (MacCrimmon 1977). The Chum Salmon were unable to form a self-sustaining population, and stocking programs ended in 1945.

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100
No, this species does not occur near waters connected to the Great Lakes basin and/or is not mobile or able to be transported by wind or water.	0 √
Unknown	U

- Oncorhynchus keta *does not naturally occur near waters that are connected to the Great Lakes; they are being transported by environmental agencies to the Great Lakes to study their ability to survive (Crawford 2001).*
- *It is very unlikely that* Oncorhynchus keta *will be able to swim to the Great Lakes basin through streams or ponds (Crawford 2001).*
- *Chum Salmon occurs naturally in areas that are far away and not directly connected to the Great Lakes. According to ybersalmon.fws.gov chum salmon usually spawn in coastal rivers. They occupy the Chukchi and Bering Seas, disperse west along the Aleutian chain, and south into the Gulf of Alaska.*
- Oncorhynchus keta *is a pacific salmon with a wide geographic distribution. It occurs in North America from Montery, California, to the Arctic coast and east to the Mackenzie River (Salo 1991).*
- *Chum Salmon are strong swimmers that have been documented migrating about 2820 km to its spawning ground in the Yukon River from the sea (Behnke 2010).*

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0 √
Unknown	U

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a) Is this species sold at aquarium/pet/garden stores ("brick & mortar" or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100
No, this species this species is rarely/never sold.	0 √
Unknown	U

- *No research shows that it is bought by people and kept as pets, due to its size (24-48 inches long and could be up to 13 lbs in weight).*
- *An extensive review of fish sold at live fish markets and in the aquarium trade conducted by Rixon et al. (2005) did not show that* Oncorhyncus keta *is sold nearLakes Erie or Ontario.*

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0 √
Unknown	U

- Oncorhynchus keta *was one of the many salmonine fish released by American and Canadian agencies into the Great Lakes during 1870-1960 for the purpose of developing a self-sustaining populations to support food, commercial, and/or recreational fisheries (Crawford 2001).*
- *From 1908 to the 1940s,* Oncorhynchus keta *were raised in hatcheries in Michigan, Pennsylvania, and Wisconsin, for release into Lakes Superior and Lake Huron (MacCrimmon 1977). The Chum Salmon were unable to form a self-sustaining population, and stocking programs ended in 1945.*
- *Chum Salmon have been introduced into Bannock County, Idaho (Simpson and Churchill County (probably Lahontan Reservoir); Damariscotta, Megunticook, and Swan lakes, Maine Deep Lake in Oakland County, Michigan; Mineral Count, and Washoe County (probably Truckee River), all in the Lahontan drainage, Nevada and non-specific sites in Nevada; and Strawberry Reservoir and Fish Lake in Utah (Fuller 2006). Most of the populations did not survive.*

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is likely to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces), this activity may occur within 20 km of the basin because of the species' popularity/value.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100
No, this species is not commercially cultured in or transported through the Great Lakes region.	0 √
Unknown	U

- *The species does not natively exist in the Great Lakes region and as a result it is most likely not cultured in or transported through this region.*

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100

Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40
No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0 √
Unknown	U

- *According to Hale et al. (1985), temperature and other conditions affect the Chum Salmon's ability to survive and spawn.*
- *This species is able to tolerate a variety of salinities (Clarke and Hirano 2010).*

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5
Yes, but this species has neither been observed in ballast/fouling ships entering the Great Lakes nor in ports in direct trade with the Great Lakes.	Score x 0.1
No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0
Unknown	U

Vector Potential Scorecard				
Vector	**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind	**0**	x	**0**	Unlikely
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.	**0**	x	**0**	Unlikely
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)	**0**	x	**0**	Unlikely
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)	**0**	x	**0**	Unlikely
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)	**0**	x	**0**	Unlikely
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling	**0**	x	**0**	Unlikely
Total Unknowns (U) — **0**		**Confidence Level**	High	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

ESTABLISHMENT POTENTIAL RESULTS

Status: **Not established in the continental United States (Alaska), including the Great Lakes**

***Oncorhynchus keta* has a moderate probability of establishment if introduced to the Great Lakes (Confidence level: High).**

The native ranges of *Oncorhynchus keta* have similar climatic conditions as the Great Lakes. *Oncorhynchus keta* can tolerate a broad range of salinity and survive abrupt changes in salinity (Clarke and Hirano 2010). Optimal water temperatures for *Oncorhynchus keta* are between 5-27°C (Hale et al. 1985). This species experiences high mortality when dissolved oxygen drops below 2 mg/L.

Oncorhynchus keta is capable of surviving winter temperature in the Great Lakes, but its ability to overwinter is limited by its oxygen requirements. There are populations of *Oncorhynchus keta* that overwinter in the North Pacific, the Gulf of Alaska, and the Bering Sea (Urawa et al. 2004), usually in waters that are 4-6°C. During homing migration, Chum Salmon make vertical diel movements to deeper waters to feed, experiencing temperatures under 5°C regularly (Azumaya and Ishida 2005). Although Chum Salmon can tolerate such low temperatures, it may not be able to for long periods of time, and behaviorally avoids them by moving to shallower waters periodically.

Oncorhynchus keta opportunistically feeds on zooplankton, invertebrates, mollusks, and fishes, and has a relatively broad diet compared to other *Oncorhynchus* species (Behnke 2010, Kaeriyama et al. 2004). The Chum Salmon fry feed on small invertebrates as they migrate downstream and on crustaceans as they move into estuaries. *Oncorhynchus keta* will likely find an appropriate food source if introduced to the Great Lakes. Alewife, *Alosa pseudoharengus*, is an established nonindigenous species in the Great Lakes and may provide a food source for introduced salmon (Crawford 2001), such as *Oncorhynchus keta*.

For successful reproduction, Chum Salmon require loose streambed gravel to lay their eggs (Bakkala 1970). Chum Salmon migrate upstream to rivers to spawn, can reproduce successfully in intertidal zones at the mouth of streams (Behnke 2010) and in lakes with upwelling groundwater (Wilson 2006). Chum Salmon migrate upstream to spawn at temperatures under 15°C and dissolved oxygen levels greater than 6.3 mg/L (Hale et al. 1985). They have been observed migrating upstream in waters that are as low as 4.4°C, and temperatures above 25.5°C are lethal. The Chum Salmon fry prefer temperatures of 12-14°C, and have lethal water temperature limits above 23.8°C and below -0.1°C (Brett and Alderdice 1958). Chum fry undergoes developmental changes for life in sea water, and migration to sea water within the first summer is necessary for survival (Hale et al. 1985); however, chum salmon have been reared to maturity in freshwater in captivity (R.L. Burgner pers. comm. in Salo 1991).

Previous introductions of *Onchorhynchus keta* to the Great Lakes did not result in the establishment of self-sustaining populations (Crawford 2001, MacCrimmon 1977). It was also introduced to the Gulf of Riga, in the bay of the Baltic Sea, but has only been found in small numbers (Ojaveer 1995). *Oncorhynchus keta* is predicted by Kolar and Lodge (2002) to be intentionally introduced to the Great Lakes for the purpose of aquaculture or sport, and will spread at a fast rate if introduced. Although Kolar and Lodge (2002) predict high probability of establishment and spread, the history of this species in the Great Lakes, which includes nearly 40 years of stocking, suggest that some unknown factors prevent its establishment in the Great Lakes region.

There have been several studies conducted on how climate change affects Chum Salmon, but none have predicted how climate change in the Great Lakes may impact Chum Salmon establishment. In the subarctic North Pacific, increased Chum fingerling growth rates correlated with increased zooplankton biomass as a result of climate change in the late 1980s (Seo et al. 2006). In the Gulf of Alaska, Chum Salmon diets switched from one dominated by gelatinous zooplankton to one with greater diversity of zooplankton species due to climate alterations caused by El Niño and La Niña events (Kaeriyama et al. 2004). Models developed by Harvey et al. (2012) predict that Chum Salmon post-spawning carcasses will decompose at a faster rate due to warming and climate change. Chum Salmon are a major component of overwintering bald eagle diets in the Puget Sound, and faster carcass decomposition rate may decrease the biomass of carcasses available for the bald eagles. The effects of climate change such as warmer water temperatures and shorter duration of ice cover may aid the establishment of *Oncorhynchus keta* and enable it to overwinter in the Great Lakes. Chum Salmon fry require migration to seawater (Hale et al. 1985), so increased salinization may increase their survival in the Great Lakes.

This species may be vulnerable to habitat degradation. Chum Salmon populations that spawned in the Columbia River basin had declined by the 1950s (Behnke 2010). The spawning habitat quality was degraded by upstream logging, pollution and water diversions, resulting in spawns of 1,000 to 5,000 fish. By 2011, spawning runs had attained 10,000 fish for the first time in 46 years after the implementation of habitat protection and enhancement (Behnke 2010?).

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
	8

- *Chum Salmon can survive in most ranges of salinity from fresh water lakes to the Pacific Ocean; they can tolerate all ranges. In a study done by Hasegawa et al.1987 showed the Chum Salmon maintained good osmoregulatory ability when tested by direct transfer to fresh water from salt water or by direct transfer from salt water to fresh water and the fish was able to adept and adjust its sodium concentration within 24 hours. Chum Salmon can tolerate low and high temperature between 2°C and 26°C (Arntzen 2009).*
- *Chum Salmon can live at low oxygen saturation as long as its above 2 mg/l. Chum Salmon try to avoid dissolved oxygen levels below 4.5 mg/l. Dissolved oxygen level greater then 6.3 mg/l are recommended for a successful upstream migration of anadromous salmonids and lower DO and more likely to inhibit upstream migration. In 1981 when Chum Salmon migration was blocked by low flows, crowding them in to a pool where the dissolved oxygen levels dropped below 2.0 mg/l high mortalities of salmon was reported is southeast Alaska streams (Hale et al. 1985). Chum Salmon have different diets when their in fresh water compared to when they are in oceans; they eat a wide verity of food which range from small fishes to some insects and stoneflies.*
- *Chum salmon are able to resist changes in salinity (Clarke and Hirano 2010).*
- Oncorhynchus keta *may be vulnerable to habitat degradation. Chum Salmon populations that spawned in the Columbia River basin had declined by the 1950s (Behnke 2010). The spawning habitat quality was degraded by upstream logging, pollution and water diversions, resulting in spawns of 1,000 to 5,000 fish. By 2011, spawning runs had attained 10,000 fish for the first time in 46 years after the implementation of habitat protection and enhancement.*

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9
Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
	6

- *Studies done by (Hale et al. 1985) showed high mortality in Chum Salmon when dissolved oxygen levels dropped below 2 mg/L, salmon avoid migrating up stream when dissolve oxygen levels drop below 4.5 mg/L. the study by the united states energy department found that the range of temperature for salmon is between 5 and 27 degree Celsius. No Chum has yet been found in waters below 5°C.*
- *On the contrary, a study conducted by Azumaya and Ishida (2005) on the thermoregulation of Chum Salmon during diel movements found that the fish do occur in water less than 5°C during the day to feed in the Bering Sea. It can tolerate low temperatures, but behaviorally avoids them for long periods of time by making vertical diel movements.*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
	7

- *Chum Salmon fry feed on small invertebrates as they move downstream and on crustaceans as they move into estuaries (Behnke 2010).*
- *Adult chum opportunistically feed on invertebrates, mollusks, and fishes (Behnke 2010).*

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	0

Unknown	U
	9

- *Open lake environment studies have shown that introduced salmons forage voraciously on the same species that is dominant in lakes char diets, causing declines in Alewife population. Introduced salmonids outcompeted smaller native species for limited food cover and stream positions (Crawford 2001).*

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
	3

- *Chum Salmon reproduce once in their life time, they need about four years to sexually mature. Usually Chum Salmon spend about 4 years in the ocean and then migrate to fresh water where they spawn and die after 2 weeks. Salmon return to their place of birth to spawn. They choose rivers and lakes where the water flows and cooler water (Crawford 1985). Chum Salmon migrate to their place of birth when the dissolved oxygen concentration is above 6.5 mg/L (Alaska Department of Fish and Game 2015).*
- *Chum Salmon are semelparous and anadromous (Salo 1991).*
- *Chum Salmon eggs are more resisant to saltwaters than Coho, Chinook, and Sockeye Salmon (Clarke and Hirano 2010).*
- *Chum Salmon fecundity ranges from 900 to 8,000 eggs (Bakkala 1970).*

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
	0

- *Stocking of* Oncorhynchus keta *stopped in 1945 after unsuccessful attempts to creating a self-sustaining chum salmon population in the Great Lakes (Crawford 2001).*
- *Chum Salmon eggs and fry exhibit a greater salinity resistance than Coho, Chinook, and Sockeye Salmon (Clarke and Hirano 2010).*

- *Eggs can survive varying levels of salinities (Behnke 2010). Successful reproduction can occur at the intertidal zones at the mouths of streams.*

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- *The air temperature, precipitation, seasonality of native range (North Pacific) is similar to the Great Lakes. Chum Salmon can tolerate a wide range of temperatures from 5°C to 27°Celsius (Hale et al. 1985).*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- *Chum Salmon are very adaptive species that can tolerate a wide range of environments, the fish have well developed kidneys to handle the salinity changes when the fish migrate between salt and fresh water.*
- *All the requirements that Chum Salmon need to live and reproduce are available in the Great Lakes from dissolved oxygen concentration to temperature. Chum Salmon has the ability to adapt very fast to salinity (Clarke and Hirano 2010).*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3

Scarce (Suitable habitats are rarely found)	0
Unknown	U
	8

- *In the study done by (Crawford 2001) shows that salmon migrate within the lake to areas with suitable conditions.*
- *A population of Chum Salmon has spawned in Kluane Lake where there is upwelling groundwater (Wilson 2006).*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0
Unknown	U
	4

- *There have been several studies conducted on how climate change affects Chum Salmon, but none have predicted how climate change in the Great Lakes may impact Chum Salmon establishment.*
- *Increased fingerling growth rates correlated with increased zooplankton biomass as a result of climate change in the late 1980s in the subarctic North Pacific (Seo et al. 2006).*
- *In the Gulf of Alaska, Chum Salmon diets switched from one dominated by gelatinous zooplankton to one with greater diversity of zooplankton species due to climate alterations caused by El Niño and La Niña events (Kaeriyama et al. 2004).*
- *Models developed by Harvey et al. (2012) predict that Chum Salmon carcasses as a result from spawning will decompose at a faster rate due to warming and climate change. Chum Salmon are a major component of overwintering bald eagle diets in the Puget Sound, and faster carcass decomposition rate may decrease the biomass of carcasses available for the bald eagles.*
- *Waters temperatures that are too high may be detrimental for chum salmon survival (≥23.8°C) and reproduction (≥25.5°C) (Brett and Alderdice 1958, Hale et al. 1985).*
- *Great Lakes' water temperatures in the winter are around the lower limit for this species (4-6°C) (Urawa et al. 2004).Warmer water temperatures and shorter duration of ice cover may aid the establishment of this species.*
- *Chum salmon cannot tolerate low oxygen levels caused by ice cover (Hale et al. 1985), so shorter duration of ice cover may benefit this species.*
- *Chum fry develop a physiology that requires sea water for survival as it matures (Hale et al. 1985), so the Great Lakes would be more suitable for chum salmon establishment if it exhibited increased salinization.*

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may	9

be considered potential food items—are highly abundant and/or easily found)	
Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
	7

- *Chum Salmon have a very similar diet to King Salmon (*Oncorhynchus tshawytscha*), the latter of which has successfully been introduced into the Great Lakes. They both consume insects and invertebrates while in rivers, and fish while in the ocean. However, Chum Salmon also consume mollusks, squid and tunicates while in the ocean, which are not available in the Great Lakes (NOAA Fisheries 2014).*

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Great Lakes and is not likely to be introduced	-80% total points (at end)
Unknown	U
	9

- *Chum Salmon does not require any other species to reproduce.*

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species	9

aiding the establishment of this species in other areas)	
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes)	6
Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0
Unknown	U
	4

- *Alewife is not native to the Great Lakes (USGS) but does provide a food source for introduced salmon. It would be expected that Alewife would be a food source for* Oncorhynchus keta *as well (Crawford 2001).*

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0
Unknown	U
	0

- *While viral hemorrhagic septicemia affects salmon populations (including Chum Salmon), is has not eliminated any salmon species and is thus unlikely to be responsible for complete prevention.*

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9
Frequent, moderate inocula	6
Frequent, small inocula OR infrequent, large inocula	3

Infrequent, small or moderate inocula	0
Unknown	U
	2

- *Introduction of Chum Salmon to the Great Lakes started in the 1870s by American and Canadian fishery agencies (Crawford 2001). Recently no major introduction events have occurred in the Great Lakes, or at least no documentation is available to say otherwise.*

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
	3

- *Chum Salmon depends on fresh water to reproduce and they have big native areas in the northern Pacific that extend from the Yukon River to waters just outside of Alaska (Alaska Department of Fish and Game 2015). The species was introduced to the Great Lakes due to direct introduction by humans from the 1870s to 1960s (Crawford 2001).*
- Oncorhynchus keta *was released into the Gulf of Riga in the 1970s, but have only been found in small numbers (Ojaveer 1995).*

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
	0

- *Most catch and release in the Great Lakes occur within the living range of Chum Salmon therefore the spread is very slow and is dependent on the food abundance because salmon is documented to migrate to areas with high food abundant (Crawwford 2001)*

- Oncorhynchus keta *is predicted by Kolar and Lodge (2002) to be intentionally introduced to the Great Lakes for the purpose of aquaculture or sport, and will spread at a fast rate if introduced.*

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing the establishment and spread of this species)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent the establishment and/or spread of this species	0
Unknown	U
	0

- *No control methods have been set to prevent the establishment or spread of this species in the Great Lakes.*

Establishment Potential Scorecard				
Points	**Probability for Establishment**	A. Total Points (pre-adjustment)		86
>100	High	**Adjustments**		
		B. Critical species	A*(1- 0%)	86
51-99	Moderate	C. Natural enemy	B*(1- 0%)	86
		Control measures	C*(1- 0%)	86
0-50	Low	**Potential for Establishment**		Moderate
# of questions answered as "unable to determine"	**Confidence Level**			
0-1	High	Total # of questions unknown		0
2-5	Moderate			
6-9	Low	Confidence Level		High
>9	Very low			

Section C: Potential for Impact

<u>IMPACT POTENTIAL RESULTS</u>

Environmental: Moderate

Socio-Economic: Low

Beneficial: High

***Oncorhynchus keta* has the potential for moderate environmental impact if introduced to the Great Lakes.**

Chum Salmon can hybridize with Chinook and Kokanee Salmon (Sasaki et al. 1968, Seeb et al. 1993), popular sport fish in the Great Lakes, but there is no indication that it can hybridize with fish native to the Great Lakes. Introduced salmon, such as Chum Salmon, may compete with native species for food (Crawford 2001), but what species will be impacted by the introduction of Chum Salmon has not been investigated. Crawford (2001) suggested that, as vectors for parasites, hatchery-reared salmon may threaten native fish species. Sea lice (*Lepeophtheirus salmonis*) infection rates in wild juvenile Chum Salmon and Pink Salmon were higher for populations that occurred near salmon farms than those that were not located near salmon farms in British Columbia, Canada (Morton et al. 2004). Sea lice are ectooparasites that can infect other salmonoid species, but fall off the host when they migrate to freshwater. When Chum Salmon create breeding nests, they create a small depression in the gravel, which may cause mild effects on the physical habitat.

There is little or no evidence to support that *Oncorhynchus keta* has the potential for significant socio-economic impacts if introduced to the Great Lakes.

It has not been reported that *Oncorhynchus keta* poses a threat to human health or water quality. There is no evidence that this species negatively impacts infrastructure, economic sectors, recreational activities and associated tourism, or the aesthetic appeal of the areas it inhabits.

***Oncorhynchus keta* has the potential for high beneficial impact if introduced to the Great Lakes.**

Oncorhynchus keta quality deteriorates as it develops for spawning, and those that are ready to spawn are not often sold in the United States (Behnke 2010). In commercial fisheries, *Oncorhynchus keta* has a lower value than other salmon species such as Chinook, Coho, or Sockeye Salmon due to its low fat content and pale pink flesh that are not preferable to consumers. *Oncorhynchus keta* is usually caught from commercial fisheries to be canned. It is sometimes sold fresh or frozen under the name of "silver bryte salmon". Native Americans in Canada and Alaska eat Chum Salmon, as well as dry and smoke the fish to feed their dogs.

In Japan, Chum Salmon goes by the name "sake", and is ranched there (Behnke 2010). Chum Salmon meat is used in sushi and sashimi. Chum Salmon that have reached sexual maturity and have spawned-out are harvested for their thick, tough skin to create salmon leather.

POTENTIAL ENVIRONMENTAL IMPACT

NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1
Not significantly	0 √
Unknown	U

- *In general, hatchery-reared salmon may present new parasites and instigate a risk to the native fish (Crawford 2001).*
- *Of all the Great Lakes species, native salmonines (Lake Charr, Brook Charr) are likely the most susceptible to these new diseases and parasites. The intensive culture of hatchery-reared salmonines poses a threat to native fishes by artificially increasing the disease and 'parasite 'reservoir that native fishes are exposed to in the wild (Crawford 2001). However, the risk of Chum Salmon parasites infecting native fish of the Great Lakes has not been studied.*
- *Sea Lice (*Lepeophtheirus salmonis*) infection rates in wild juvenile Chum Salmon and pink salmon were higher for populations that occurred near salmon farms than those that were not located near salmon farms in British Columbia, Canada (Morton et al. 2004). Sea Lice are ectooparasites that can infect other salmonoid species, but fall off the host when they migrate to freshwater.*

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1 √
Not significantly	0
Unknown	U

- *In open lake environments, studies have shown that introduced salmonids forage voraciously on the same species that is dominant in Lake Charr diets (the declining of alewife populations (Crawford 2001). Alewifes are non-native.*
- *Introduced salmonids outcompete smaller, native fish species for limited food, cover, and stream positions (Crawford 2001).*

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in the food web)	6
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	1 √

Not significantly	0
Unknown	U

- *Predation by salmonids on native species in the Great Lakes is a major problem because the stocked fish are 'generalist' vertebrate predators that can feed on numerous prey (Crawford 2001).*

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0 √
Unknown	U

- *In both tributaries and open lake environments of the Great Lakes, introduced salmon have affected native fish populations though hybridization and introgression (Crawford 2001).*
- *Chum Salmon can hybridize with Chinook Salmon and Koanee Salmon, which are not native to the Great Lakes (Seeb et al. 1993, Sasaki et al. 1968).*
- *Chum and Pink Salmon are closely related and may spawn in the same streams but avoid hybridization by spawning at a different time or at a different spawning ground (Behnke 2010). These two species are able to produce fertile hybrids, but no self-sustaining hybrid populations are known. Pink Salmon are not native to the Great Lakes.*

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1
Not significantly	0 √
Unknown	U

- *Introduced salmonids migrating into tributaries in the Great Lakes have shown to increase levels of limiting nutrients and toxins accumulated while in the open lakes which changes the community ecology in these tributaries (Crawford 2001).*

E6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1 √

Not significantly	0
Unknown	U

- *The physical alterations of digging nests or superimpose their redds have been shown to have community-level effects on the abundance and distribution of native fishes and invertebrates in the tributaries. Spawning runs of introduced salmonids have also been shown to transport significant levels of contaminants upriver from the lakes (Crawford 2001).*

Environmental Impact Total	**3**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	**Moderate**
0	0-1	Low
1	0	
0	≥2	Unknown
1	≥1	

POTENTIAL SOCIO-ECONOMIC IMPACT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1
Not significantly	0
Unknown	U √

- *Salmon are semelparous, which means they migrate upstream to spawn and die shortly afterwards. The migration of salmon upstream to spawn and die createas a carass-loading event in a small geographic area. Recent literature has suggested that spawning salmon are a potential contaminant biovector (Behnke 2010).*

S2) Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1
Not significantly	0 √
Unknown	U

- *There is no evidence showing Chum Salmon causes infrastructure damage.*

S3) Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0 √
Unknown	U

- *There is no evidence that Chum Salmon negatively affect water quality for human use.*

S4) Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

- *There is no evidence that Chum Salmon negatively affect any markets or economic sectors.*

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

- *No significant research indicates Chum Salmon are associated with frequent water closures, equipment damage, or a decline of recreational species.*

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

Socio-Economic Impact Total	**0**
Total Unknowns (U)	**1**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**<u>Low</u>**
1	0	
0	≥2	Unknown
1	≥1	

<u>POTENTIAL BENEFICIAL EFFECT</u>

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular effect. An "Unknown" response is appropriate if the potential for a particular effect might be inferred but has not been explicitly reported or if there is an unresolved debate about a particular effect.

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1
Not significantly	0 √
Unknown	U

B2) Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?

Yes, it is economically important to at least one of these industries	6 √
Yes, but its economic contribution is small	1
Not significantly	0
Unknown	U

- *In Southeast Alaska, Chum Salmon are important to the commercial fishing industry.*
- Oncorhynchus keta *quality deteriorates as it develops for spawning, and those that are ready to spawn are not often sold in the United States (Behnke 2010).*
- *In commercial fisheries,* Oncorhynchus keta *has a lower value than other salmon species such as Chinook, Coho, or Sockeye salmon due to its low fat content and pale pink flesh that are not preferable to consumers (Behnke 2010).*

- *Oncorhynchus keta is usually caught from commercial fisheries to be canned. It is sometimes sold fresh or frozen under the name of "Silver Bryte Salmon" (Behnke 2010).*

B3) Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local communities and/or tourism	6 √
It is sometimes employed recreationally, but adds little value to local communities or tourism	1
Not significantly	0
Unknown	U

- *Chum Salmon support many fisheries in the Puget Sound area. These include sport, commercial (all-citizen), and tribal fisheries. Recreational fisheries exist when mature adults return from the Strait of Juan de Fuca through Puget Sound and Hood Canal to their stream of origin. Commercial and tribal fisheries use purse seine or gillnets in open areas (WDFW 2012).*
- *Natives in Canada and Alaska dry and smoke these fish to feed to their dogs (Behnke 2010).*

B4) Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR It is potentially important to medicine or research and is currently being or scheduled to be studied	1
Not significantly	0 √
Unknown	U

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1
Not significantly	0 √
Unknown	U

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1
Not significantly	0 √
Unknown	U

Beneficial Effect Total	**12**
Total Unknowns (U)	**0**

Scoring		
Score	# U	**Impact**
>5	Any	**<u>High</u>**
2-5	Any	Moderate
0	0-1	Low
1	0	
0	≥2	Unknown
1	≥1	

Scientific Name: *Osmerus eperlanus* Linnaeus, 1758

Common Name: European Smelt

Synonyms:

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: Unlikely

Hitchhiking/fouling: Unlikely

Unauthorized intentional release: Unlikely

Stocking/planting/escape from recreational culture: Unlikely

Escape from commercial culture: Unlikely

Transoceanic shipping: Moderate

***Osmerus eperlanus* has a moderate probability of introduction to the Great Lakes (Confidence level: High).**

Potential pathway(s) of introduction: Transoceanic Shipping

Osmerlus eperlanus lives and spawns in the Elbe River (Thiel and Potter 2001), which is an extremely busy shipping route. In the Netherlands, *Osmerus eperlanus* larvae survive transport in water pumped from Lake llsselImeer to the Frisian lake district to maintain a constant water level for agricultural purposes (Lammens et al. 1985). There was found to be 80% survival of *O. eperlanus* after intake of a cooler water inflow to a power plant through a screen system (Rohlwing et al. 1998). Thus this species is considered likely to survive transport in a ballast tank.

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100
No, this species does not occur near waters connected to the Great Lakes basin and/or is not mobile or able to be transported by wind or water.	0 √
Unknown	U

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0 √
Unknown	U

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a) Is this species sold at aquarium/pet/garden stores ("brick & mortar" or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100
No, this species this species is rarely/never sold.	0 √
Unknown	U

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1

This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0 √
Unknown	U

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is <u>likely</u> to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces), this activity <u>may</u> occur within 20 km of the basin because of the species' popularity/value.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100
No, this species is not commercially cultured in or transported through the Great Lakes region.	0 √
Unknown	U

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes	Score x 0.75

tributaries or connecting waters, or within 20 km of the Great Lakes basin.	
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80 √
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40
No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0
Unknown	U

- *In the Netherlands,* O. eperlanus *larvae survive transport in water pumped from Lake llsselImeer to the Frisian lake district to maintain a constant water level for agricultural purposes (Lammens et al. 1985).*
- *There was found to be 80% survival of* O. eperlanus *after intake of a cooler water inflow to a power plant through a screen system (Rohlwing et al. 1998).*

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5 √
Yes, but this species has neither been observed in ballast/fouling ships entering the Great Lakes nor in ports in direct trade with the Great Lakes.	Score x 0.1
No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0
Unknown	U

- Osmerlus eperlanus *lives and spawns in the Elbe River (Thiel and Potter 2001), which is an extremely busy shipping route.*
- *Its native range includes coastal waters and estuaries from southern Norway, around the western coast of Europe (including the Baltic Sea), to north-western Spain (Jakob et al. 2010).*

Vector Potential Scorecard					
Vector		**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind		**0**	x	**0**	Unlikely
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.		**0**	x	**0**	Unlikely
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)		**0**	x	**0**	Unlikely
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)		**0**	x	**0**	Unlikely
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)		**0**	x	**0**	Unlikely
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling		**80**	x 0.5	**40**	Moderate
Total Unknowns (U)	**0**	**Confidence Level**		High	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

<u>ESTABLISHMENT POTENTIAL RESULTS</u>

Status: **Not established in North America, including the Great Lakes**

***Osmerus eperlanus* has a moderate probability of establishment if introduced to the Great Lakes (Confidence level: High).**

Osmerus eperlanus lives in large lakes in Finland, Sweden, Norway, Denmark, Poland and Russia (Nellbring 1989) with conditions similar to the more oligotrophic of the Great Lakes. Scandinavian lakes would have similar temperature regimes as the Great Lakes. Congeneric species (*Osmerus mordax*) have already been introduced into the Great Lakes and spread throughout the region (Nellbring 1989). This indicates (though does not guarantee), the suitability of the Great Lakes for this species' survival and spread. *Osmerus eperlanus* are tolerant of a wide salinity range; several purely freshwater populations occur (Jakob et al. 2010). *Osmerus eperlanus* are opportunistic feeders, likely to readily find sufficient food in the Great Lakes. This species has a relatively high rate of hermaphroditism and can be self-fertile.

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
	7

- O. eperlanus *is tolerant of a wide salinity range; several purely freshwater populations occur (Jakob et al. 2010).*
- Osmerus eperlanus *does particularly well in pelagic areas of oligotrophic lakes (Jurvelius et al. 2005).*
- O. eperlanus *is a coldwater species that does not tolerate surface water temperatures over 20°C for long periods (~80 days) (Kangur et al. 2007b). However, this species is able to migrate to deeper, cooler waters during the summer (Power and Attrill 2007).*
- O. eperlanus *is sensitive to cyanobacteria blooms (Kangur et al. 2007b).*
- *This species does not tolerate low oxygen (<2 mg O_2/l) in warm water temperatures (Kangur et al. 2007b), low growth at <4.5 mg O_2/l (Sepulveda 1994) .*
- O. eperlanus *does less well in eutrophic waters, in part because associated siltation may lead to inconsistent recruitment of fish through spawning grounds (Kangur et al. 2007, Winfield et al. 1996).*
- O. eperlanus *can inhabit turbid river stretches (Lyle and Maitland 1997), and has been the dominant catch (91.8-100%) in eutrophic and turbid lakes in Finland (Peltonen et al. 2006, Reckel et al. 2003).*

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9

Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
	9

- Osmerus eperlanus *lives in large lakes in Finland, Sweden, Norway, Denmark, Poland and Russia (Nellbring 1989).*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
	6

- *An opportunistic feeding ecology,* O. eperlanus *consumes copepods and cladocerans (Northcote and Hammar 2006).*
- *With increasing size and age, its food changes to larger crustaceans and in some cases to fish (Nilsson 1979, Svärdson et al. 1988). According to Sterligova (1979) European Smelt also eats Vendace, Whitefish larvae and fry (Jurvelius et al. 2005).*

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	0
Unknown	U
	7

- *Jurvelius et al. (2005) did a study of* O. eperlanus *in 5 Finnish lakes: In four lakes the proportion of European Smelt was more than 60%.*
- *Young* O. eperlanus *are efficient planktivorous fish that affect the size structure of the zooplankton community easily by their size selective predation (van Densen 1985). When the density of smelt is very high, the*

depression of the average size of D. hyalina *is so drastic that these food organisms can no longer be retained by the gill rakers of mature bream (Lammens et al. 1985), which has to switch to a benthivorous diet (Lammens et al. 1985).*

- O. eperlanus *can reach very high densities (Northcote and Hammar 2006).*
- *Evidence from congeneric species: In the Great Lakes, Rainbow Smelt* Osmerus eperlanus *compete with Lake Herring* Coregonus artedii *for food (Becker 1983). Christie (1974) supplied some evidence to support this, correlating Lake Herring decline with Rainbpw Smelt increases in most of the lakes. Todd (1986) also reported that Smelt may be partially responsible for the decline of Whitefish* Coregonus *spp. in the Great Lakes. Hrabik et al. (1998) found evidence of competition for food between introduced Rainbow Smelt and native Yellow Perch* Perca flavescens *in Wisconsin lake habitats (Fusaro et al. 2015).*

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
	7

- *Relative fecundity of* O. eperlanus *ranged 980-1718 eggs/g female (Nellbring 1989).*
- *Relative fecundity of* O. mordax *ranged 380-656 eggs/g female (Nellbring 1989).*
- *Relative fecundity of* O. dentex *ranged 491-1063 eggs/g female (Nellbring 1989).*
- *Relative fecundity of Surf Smelt* Hypomesus pretiosus *average 556.5 eggs/g female (Therriault and Hay 2003).*
- O. eperlanus *is highly fecund with a mean fecundity of 56,603 eggs/female (Hutchinson and Mills 1987). Fecundity is also estimated at 30,360 eggs/female, with average weight of fish 116.35 (Maitland and Lyle 2010).*
- *Maximum fecundity of Pond Smelt* Hypomesus olidus *was 2523 eggs/female, with maximum weight 50 g (Degraaf 1986).*
- *Review of Landlocked Smelt maximum fecundity (eggs/fish) revealed (Chigbu and Sibley 1994):*
    - O. eperlanus*: 4100-20000.*
    - O . mordax*: 5500-40900.*
    - Spirinchus thaleichthys*: 535-22210.*

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3

Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
	3

- O. eperlanus *exhibits relatively high rates of hermaphroditism: 2.6% of fish from the Elbe were hermaphroditic, and capable of self-fertilization, with other reports at 3.7% (Hutchinson 1983).*

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- *Lives in large lakes in Finland, Sweden, Norway, Denmark, Poland and Russia (Nellbring 1989).*
- *Congeneric species (*Osmerus mordax*) have already been introduced into the Great Lakes and spread throughout the region (Nellbring 1989). This indicates (though does not guarantee), the suitability of the Great Lakes for this species' survival and spread.*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	7

- *This species lives in pristine, oligotrophic habitats (Scandinavian inland lakes) as well as heavily-polluted habitats (lower Elbe River), though may have health issues (e.g., granulomas and physical deformities) in more polluted areas (Anders and Möller 1987, Pohl 1990).*
- *Scandinavian lakes would have similar temperature regimes as the Great Lakes.*
- *Congeneric species (*Osmerus mordax*) has already been introduced into the Great Lakes and spread throughout the region (Nellbring 1989). This indicates (though does not guarantee), the suitability of the Great Lakes for this species' survival and spread.*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0
Unknown	U
	6

- Osmerus eperlanus *can inhabit freshwater lakes and rivers (Lyle and Maitland 1997, Nellbring 1989).*
- *This species does particularly well in pelagic areas of oligotrophic lakes (Jurvelius et al. 2005).*
- O. eperlanus *Inhabits pelagic zone; catches of smelt peak at 22-25 m depth (Northcote and Hammar 2006).*
- O. eperlanus *has been observed to feed at 7-9 m in a Finnish lake (Reckel et al. 2003).*
- O. eperlanus *uses warmer environments for larval development, and migrate to colder areas for growth/maturation (Power and Attrill 2007).*
- *Congeneric species (*Osmerus mordax*) has already been introduced into the Great Lakes and spread throughout the region (Nellbring 1989). This indicates (though does not guarantee), the suitability of habitat in the Great Lakes for this species' survival and spread.*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0
Unknown	U
	0

- *This species does poorly in surface water temperatures above 20°C, so would not likely benefit from increased water temperatures (Kangur et al. 2007b).*

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to	6

moderate)	
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
	7

- *During its first summer* O. eperlanus *initially eats rotifers, copepods and successively larger zooplanktons (Nellbring 1989). With increasing size and age, its food changes to larger crustaceans and in some cases to fish (Nilsson 1979, Svärdson et al. 1988). According to Sterligova (1979) smelt also eats vendace, whitefish larvae and fry (Jurvelius et al. 2005).*

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Great Lakes and is not likely to be introduced	-80% total points (at end)
Unknown	U
	9

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established	6

and spread in the Great Lakes)	
Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0
Unknown	U
	0

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0
Unknown	U
	-20%

- *Smelt is an important food item for predatory fish species like Pike-perch, Brown Trout and Landlocked Salmon (Heikinheimo et al. 2002, Keskinen and Marjomäki 2004, Jurvelius et al. 2005, Peltonen et al. 1996).*

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9
Frequent, moderate inocula	6
Frequent, small inocula OR infrequent, large inocula	3
Infrequent, small or moderate inocula	0
Unknown	U
	0

- *Uptake and survival in ballast after exchange would lead to low densities of inocula.*

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
	1

- *The native range of* O. eperlanus *is coastal waters and estuaries from southern Norway, around the western coast of Europe (including the Baltic Sea) to north-western Spain (Jakob et al. 2010). It has been introduced into several Scandinavian lakes, but not elsewhere.*

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
	1

- *This species has not been reported to spread from the landlocked lakes into which it has been introduced. However, the congeneric species* O. mordax *has spread extensively throughout the Great Lakes (Fusaro et al. 2015).*

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing the establishment and spread of this species)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are	-20% total

many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	points (at end)
No control methods have been set to prevent the establishment and/or spread of this species	0
Unknown	U
	0

Establishment Potential Scorecard				
Points	**Probability for Establishment**	A. Total Points (pre-adjustment)		78
>100	High	**Adjustments**		
		B. Critical species	A*(1- 0%)	78
51-99	Moderate	C. Natural enemy	B*(1- 20%)	62.4
		Control measures	C*(1- 0%)	62.4
0-50	Low	**Potential for Establishment**		Moderate
# of questions answered as "unable to determine"	**Confidence Level**			
0-1	High	Total # of questions unknown		0
2-5	Moderate			
6-9	Low	Confidence Level		High
>9	Very low			

Section C: Potential for Impact

IMPACT POTENTIAL RESULTS

Environmental: High

Socio-Economic: Unknown

Beneficial: Moderate

***Osmerus eperlanus* has the potential for high environmental impact if introduced to the Great Lakes.**

In the Great Lakes, congeneric Rainbow Smelt, *Osmerus mordax*, compete with Lake Herring, *Coregonus artedii*, for food (Becker 1983). Christie (1974) supplied some evidence to support this, correlating Lake Herring decline with Smelt increases in most of the lakes. Todd (1986) also reported that Smelt may be partially responsible for the decline of Whitefish *Coregonus* spp. in the Great Lakes. Hrabik et al. (1998)

found evidence of competition for food between introduced Rainbow Smelt and native Yellow Perch (*Perca flavescens)* in Wisconsin lake habitats (Fusaro et al. 2015).

Osmerus eperlanus was accidentally introduced (in or before 1968) into the ecosystem of the Syamozero lake in Karelia (north-western Russia). The population of this species has reached a high density and caused serious changes in the structure and trophic relationships of the fish community of the Syamozero ecosystem (Ieshko et al. 2000). Unfortunately, this article is in Russian and has not been translated apart from the abstract.

The resource partitioning of the Bream (*Abramis brama*) and Eel (*Anguilla anguilla*) populations in Lake Tjeukemeer, The Netherlands, was related to the variation in abundance of their most important food organisms, *Daphnia hyalina* and larval chironomids (Lammens et al. 1985). Niche shifts of both bream and eel populations were related to the abundance of young planktivorous fish, particularly Smelt (*Osmerus eperlanus*). When these fish were abundant the *D. hyalina* population was dominated by small individuals and bream switched from a planktivorous to a benthivorous diet, the condition of mature bream deteriorated, and its gonads developed poorly (Lammens et al. 1985). Under these circumstances the eel population switched from a diet of chironomid pupae and molluscs to one of predominantly fish. The condition of Eels smaller than 35 cm decreased and the chironomid population decreased in numbers and biomass (Lammens et al. 1985). Thus *O. eperlanus* has the potential to disrupt respource partitioning among native species and its introduction may have consequences for native populations of American Eel (*Anguilla rostrata*). *Osmerus eperlanus* is a paratenic host for the parasitic nematode, *Anguillicola crassus* (causing swimbladder lesions); in Europe, *Osmerus eperlanus* transmits the parasite when preyed upon by eels (Haenen et al. 1994).

Current research on the potential for socio-economic impacts to result from *Osmerus eperlanus* if introduced to the Great Lakes is inadequate to support proper assessment.

Osmerus eperlanus is the most important fish intermediate/transport host of the sealworm *Pseudoterranova dedpiens* in the Elbe estuary and probably also in adjacent coastal waters of the Wadden Sea (Rohlwing et al. 1998, Karl 2006). Sealworms are potentially capable of causing anisakiasis-like symptoms in humans (e.g. abdominal pain, nausea, fever) when consumed in lightly cooked or raw fish products (pseudoterranovosisi; Audicana and Kennedy 2008, Margolis 1977, McClelland 2002, Rae 1963, Yu et al. 2001). However, this parasite requires seals to complete its life cycle (Kuhn et al. 2013).

***Osmerus eperlanus* has the potential for moderate beneficial impact if introduced to the Great Lakes.**

The commercial value of Smelt is low in Finnish lakes (Jurvelius et al. 2005). Smelt is an important food item for predatory fish species like Pike-perch, Brown Trout and Landlocked Salmon (Heikinheimo et al. 2002, Jurvelius et al. 2005, Keskinen and Marjomäki 2004, Peltonen et al. 1996). Evidence from congeneric species: Havey (1973) reported increased growth of landlocked Atlantic Salmon following the introduction of Smelt as a forage species in a lake in Maine (Fusaro et al. 2015).

POTENTIAL ENVIRONMENTAL IMPACT

NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1
Not significantly	0
Unknown	U √

- O. eperlanus *is a paratenic host for the parasitic nematode,* Anguillicola crassus *(causing swimbladder lesions); in Europe, transmits the parasite when preyed upon by eels (Haenen et al. 1994).*

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1 √
Not significantly	0
Unknown	U

- *The resource partitioning of the Bream (*Abramis brama*) and Eel (*Anguilla anguilla*) populations in Lake Tjeukemeer, The Netherlands, was related to the variation in abundance of their most important food organisms,* Daphnia hyalina *and larval chironomids (Lammens et al. 1985). Niche shifts of both bream and eel populations were related to the abundance of young planktivorous fish, particularly Smelt (*Osmerus eperlanus*). When these fish were abundant the* D. hyalina *population was dominated by small individuals and bream switched from a planktivorous to a benthivorous diet, the condition of mature bream deteriorated, and its gonads developed poorly (Lammens et al. 1985). Under these circumstances the eel population switched from a diet of chironomid pupae and molluscs to one of predominantly fish. The condition of eels smaller than 35 cm decreased and the chironomid population decreased in numbers and biomass (Lammens et al. 1985).*
- *Evidence from congeneric species: In the Great Lakes, rainbow smelt* Osmerus eperlanus *compete with Lake Herring* Coregonus artedii *for food (Becker 1983). Christie (1974) supplied some evidence to support this, correlating Lake Herring decline with Smelt increases in most of the lakes. Todd (1986) also reported that smelt may be partially responsible for the decline of Whitefish* Coregonus *spp. in the Great Lakes. Hrabik et al. (1998) found evidence of competition for food between introduced Rainbow Smelt and native Yellow Perch* Perca flavescens *in Wisconsin lake habitats (Fusaro et al. 2015).*

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in the food web)	6 √
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR	1

Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	
Not significantly	0
Unknown	U

- *The European Smelt* Osmerus eperlanus *was accidentally introduced (in or before 1968) into the ecosystem of the Syamozero lake in Karelia (north-western Russia). The population of this species has reached a high density and caused serious changes in the structure and trophic relationships of the fish community of the Syamozero ecosystem (Ieshko et al. 2000).*

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0 √
Unknown	U

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1
Not significantly	0 √
Unknown	U

E6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1
Not significantly	0 √
Unknown	U

Environmental Impact Total	**7**
Total Unknowns (U)	**1**

Scoring		
Score	# U	**Impact**
>5	Any	**<u>High</u>**
2-5	Any	Moderate
0	0-1	Low
1	0	Low
0	≥2	Unknown
1	≥1	Unknown

<u>POTENTIAL SOCIO-ECONOMIC IMPACT</u>

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1
Not significantly	0
Unknown	U √

- Osmerus eperlanus *is the most important fish intermediate/transport host of the Sealworm* Pseudoterranova dedpiens *in the Elbe estuary and probably also in adjacent coastal waters of the Wadden Sea (Karl 2006, Rohlwing et al. 1998). Sealworms are potentially capable of causing anisakiasis-like symptoms in humans (e.g. abdominal pain, nausea, fever) when consumed in lightly cooked or raw fish products (pseudoterranovosisi) (Audicana and Kennedy 2008, Margolis 1977, McClelland 2002, Rae 1963, Yu et al. 2001). However, this parasite requires seals to complete its life cycle (Kuhn et al. 2013).*

S2) Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1
Not significantly	0 √
Unknown	U

S3) Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0 √
Unknown	U

S4) Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0
Unknown	U √

- O. eperlanus *carries the herpesvirus of* Osmerus eperlanus *(HVOE1) or Comet herpesvirus of Smelt. In fish farming other herpesviruses are known to cause economic losses (Jakob et al. 2010).*
- Osmerus eperlanus *is the most important fish intermediate/transport host of the Sealworm* Pseudoterranova dedpiens *in the Elbe estuary and probably also in adjacent coastal waters of the Wadden Sea (Karl 2006, Rohlwing et al. 1998). This leads to commercial losses for the seafood processing industry, due to the presence of these worms in the fillets of many important food fishes (e.g. Gadu*s morhua, Pollachius virens, Hippog jossus *sp.) (Kuhn et al. 2013).*

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

Socio-Economic Impact Total	**0**
Total Unknowns (U)	**2**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	Low
1	0	
0	≥2	**Unknown**
1	≥1	

POTENTIAL BENEFICIAL EFFECT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular effect. An "Unknown" response is appropriate if the potential for a particular effect might be inferred but has not been explicitly reported or if there is an unresolved debate about a particular effect.

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1
Not significantly	0 √
Unknown	U

B2) Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?

Yes, it is economically important to at least one of these industries	6
Yes, but its economic contribution is small	1 √
Not significantly	0
Unknown	U

- *The commercial value of Smelt is low in Finnish lakes (Jurvelius et al. 2005).*

B3) Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local communities and/or tourism	6

It is sometimes employed recreationally, but adds little value to local communities or tourism	1 √
Not significantly	0
Unknown	U

- *The recreational value of Smelt is low in Finnish lakes (Jurvelius et al. 2005).*

B4) Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR It is potentially important to medicine or research and is currently being or scheduled to be studied	1
Not significantly	0 √
Unknown	U

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1
Not significantly	0 √
Unknown	U

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1 √
Not significantly	0
Unknown	U

- *Smelt is an important food item for predatory fish species like Pike-perch, Brown Trout and Landlocked Salmon (Heikinheimo et al. 2002, Jurvelius et al. 2005, Keskinen and Marjomäki 2004, Peltonen et al. 1996).*
- *Evidence from congeneric species: Havey (1973) reported increased growth of landlocked Atlantic Salmon following the introduction of Smelt as a forage species in a lake in Maine (Fusaro et al. 2015).*

Beneficial Effect Total	**3**

Scoring		
Score	# U	Impact

>5	Any	High
2-5	Any	**<u>Moderate</u>**
0	0-1	Low
1	0	
0	≥2	Unknown
1	≥1	

Scientific Name: *Perca fluviatilis*
Linnaeus, 1758

Common Name: European Perch, Eurasian Perch, River Perch, Redfin Perch

Synonyms:

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: Unlikely

Hitchhiking/fouling: Unlikely

Unauthorized intentional release: Unlikely

Stocking/planting/escape from recreational culture: Unlikely

Escape from commercial culture: Unlikely

Transoceanic shipping: Moderate

***Perca fluviatilis* has a moderate probability of introduction to the Great Lakes (Confidence level: High).**

Potential pathway(s) of introduction: Transoceanic Shipping (ballast water)

Models developed by Kolar and Lodge (2002) predict that *Perca fluviatilis* will be introduced to the Great Lakes from the Ponto-Caspian basin by transoceanic shipping. *Perca fluviatilis* may be taken up by ballast water and survive in ballast tank environments. This species occurs in waters that have direct trade connections with the Great Lakes, such as the Baltic Sea (Ložys 2004, NBIC 2009). It is considered a eurythermal fish and can tolerate temperatures between 8-27°C, but becomes stressed between 23-26°C (Lehtonen 1996). However, *Perca fluviatilis* cannot tolerate high salinities, so its survival in ballast tanks environments may be limited. It can inhabit brackish waters of the Aral and Baltic Sea, up to salinities of 10 ppt (Ložys 2004), and can survive salinities of 13 ppt at water temperatures of 12-15°C. Larvae cannot tolerate salinities greater than 9.6 ppt (Lehtonen 1996). Ballast water exchange regulations requiring flushing with full strength sea water of 35 ppt may substantially limit the introduction of *Perca fluviatilis* to the Great Lakes. *Perca fluviatilis* may be introduced to the Great Lakes via ships declaring "No Ballast on Board" (NOBOB), which are exempt from ballast water exchange. The majority of ships entering the Great Lakes are NOBOB vessels and 43% of these ships contain residual water with less than 10 ppt salinity (Johengen et al. 2005). In the study, the temperature of the residual water from the vessels sampled ranged from -0.7 to 23.9°C; thus *Perca fluviatilis* is likely to survive the salinity and temperature of the NOBOB ballast water on some vessels.

As a prized freshwater angling species, *Perca fluviatilis* has been introduced to a number of countries (GISD 2012). USEPA (2008) suggests that there is a high risk that *Perca fluviatilis* will be introduced to the Great Lakes region as a sport fish. *Perca fluviatilis* does not currently occur near waters connected to the Great Lakes basin. It is not known to hitchhike on ships or recreational gear. It is not stocked, cultured, or sold in the Great Lakes region. It may survive several hours out of water if packed in dry straw (Pinnock 1820).

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100
No, this species does not occur near waters connected to the Great Lakes basin and/or is not mobile or able to be transported by wind or water.	0 √
Unknown	U

- *Eurasian Perch occur naturally in still or slow-moving waters throughout the Northern Hemisphere. This species has spread widely throughout North and South Islands of New Zealand, Australia, and Asia (Closs et al. 2011).*
- *Its native range extends throughout Europe (GISD 2012).*

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0 √
Unknown	U

- *Eurasian Perch is not recorded as a species that may be transported by fouling or hitchhiking.*

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a) Is this species sold at aquarium/pet/garden stores ("brick & mortar" or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100
No, this species this species is rarely/never sold.	0 √
Unknown	U

- *Live Eurasian Perch is not available for sale in North American or through online retailers.*

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0 √
Unknown	U

- *Eurasian Perch may be stocked as a sport fish in some locations (GISD 2012), it was stocked in Tasmania in 1862 and Victoria in 1868 as a sport and table fish (Arthington and McKenzie 1997).*
- *Eurasian Perch is a popular sport fish with some anglers because of its fighting qualities and taste (NSW DPI 2012a).*

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is likely to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces), this activity may occur within 20 km of the basin because of the species' popularity/value.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100
No, this species is not commercially cultured in or transported through the Great Lakes region.	0 √
Unknown	U

- *This species has not been reported from the United States (USFWS 2014c).*
- *Large perch (over 250 grams) are processed by several companies in Finland, but the domestic market for small perch seems to be minor. Small perch are mainly used as raw material for traditional Finnish fish pasty, kalakukko, in eastern Finland (Setälä et al. 1996).*
- *In fisheries this species is highly commercial, used for aquaculture, commercially, and for gamefish (Froese and Pauly 2015).*

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80 √
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40
No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0
Unknown	U

- *The Redfin Perch was identified as being at high risk of introduction to the Great Lakes though ballast water transported from the Ponto-Caspian basin (Kolar and Lodge 2002).*
- *It is not euryhaline. Adults can tolerate salinities up to 10 ppt, and larvae can tolerate salinities up to 9.6 ppt (Lehtonen 1996, Ložys 2004). They occur in relatively warm waters that reach about 22°C. Perch growth rate increases with increasing temperature.*
- *It can tolerate water temperatures between 8-27°C, but become stressed at temperatures of 23-26°C (Lehtonen 1996).*
- *Balast water exchange regulations requiring flushing with full strength sea water of 35 ppt may substantially limit the introduction of* Perca fluviatilis *to the Great Lakes.*

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5 √
Yes, but this species has neither been observed in ballast/fouling ships entering the Great Lakes nor in ports in direct trade with the Great Lakes.	Score x 0.1
No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0
Unknown	U

- *This species is found throughout Europe to the northernmost extremity of Scandinavia, except the Iberian Peninsula, central Italy, and Adriatic basin. It is also found in the Aegean Sea basin in Matriza and from Struma to Aliakmon drainages, Aral Sea basin, and in Siberia in rivers draining the Arctic Ocean eastward to Kolyma (Papasissi 2013).*
- *Introduced to Australia, China, Cyprus, Italy, Morocco, New Zealand, Spain and South Africa (Papasissi 2013). The species is not a true native of Ireland (although it was introduced 100s of years ago) and it is still absent from parts of Scotland. (GISD 2012).*
- *This species occurs in the Baltic Sea, off the coast of Lithuania (Ložys 2004).*

Vector Potential Scorecard				
Vector	**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind	**0**	x	**0**	Unlikely
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.	**0**	x	**0**	Unlikely
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)	**0**	x	**0**	Unlikely
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)	**0**	x	**0**	Unlikely
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)	**0**	x	**0**	Unlikely
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling	**80**	x 0.5	**40**	Moderate
Total Unknowns (U)	**0**	**Confidence Level**	High	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

ESTABLISHMENT POTENTIAL RESULTS

Status: **Established in North America, but not including the Great Lakes.**

***Perca fluviatilis* has a moderate probability of establishment if introduced to the Great Lakes (Confidence level: High).**

Perca fluviatilis occurs in Australia, which has a similar climate to most of the US, except for the Desert Southwest (USFWS 2014c). *Perca fluviatilis* has a somewhat broad physiological tolerance. It is considered a eurythermal fish and can tolerate temperatures between 4-31°C (Toner and Rougeot 2008). It can tolerate dissolved oxygen levels of 1.3-13.5 mg/L (Toner and Rougeot 2008) and salinities up to 10 ppt (Ložys 2004). *Perca fluviatilis* is likely able to overwinter in the Great Lakes. This species is known to overwinter in Lake Constance, Germany, at temperatures between 4°-6°C, but may experience depletion of lipid reserves and post-spawning mortality as a result of overwintering (Eckmann 2004). *Perca fluviatilis* requires clear waters with a considerable level of light penetration to forage effectively (Granqvist and Mattila 2004). High nutrient levels and turbidity may be detrimental to the growth and survival of this species. It is predicted by Lehtonen (1996) that increased temperatures due to climate change will result in *Perca fluviatilis* spawning later in autumn and hatching earlier. In addition, it is expected that larvae will be smaller and will be more vulnerable to possible predators. Juveniles are predicted to grow to a larger size after their first summer due to warmer water temperatures.

Perca fluviatilis is carnivorous and feeds on a wide variety of foods including insect larvae, crustaceans, and small fish (Toner and Rougeot 2008). Larvae feed on algae and zooplankton. It is likely that this species will find an appropriate food source in the Great Lakes. In its native range, *Perca fluviatilis* exhibits intraspecific competition for food with the invasive Ruffe, *Gymnocephalus cernua* (L.) (Eckmann 2004, Schleuter 2007) which also occurs as a nonnative in the Great Lakes. Both species are benthic feeders at some point of their development and both inhabit the littoral zone. *Perca fluviatilis* is a visually oriented predator and competition favors it in ogliotrophic conditions. On the other hand, the Ruffe is favored in more eutrophic conditions and can feed in turbid environments. When Ruffe is the superior competitor, there is a decline in the growth and yields of *Perca fluviatilis.*

Perca fluviatilis reproduces once a year, from March to June (Toner and Rougeot 2008). The juveniles require at least 160 days in water temperatures under 8°C to mature. The juveniles reach maturity at 2-3 years. Relative fecundity averages at 102,000 eggs/kg of body weight. A similar species, *Perca flavascens*, has a relative fecundity that ranges from 79,000-223,000 eggs/kg (Sheri and Power 1969).

Kolar and Lodge (2002) developed models that predicted that *Perca fluviatilis* has a high risk for establishment, will spread quickly, and will be a nuisance in the Great Lakes. *Perca fluviatilis* has been introduced to several countries including Australia, South Africa, China, Cyprus, Ireland, Italy, Morocco, New Zealand, Spain, and South Africa for its reputation as an angling species (Welcomme 1988). *Perca fluviatilis* growth is stunted in some waters in Cyprus (Welcomme 1988). In New Zealand, it is reproducing artificially (Welcomme 1988). The introduction of *Perca fluviatilis* to South Africa is considered marginally successful (Welcomme 1988).

In Australia, *P. fluviatilis* tends to outcompete native species (Welcomme 1988). *Perca fluviatilis* is a potential competitor with other fish that feed on invertebrates and small fish including Great Lakes native fish, such as brook trout, lake whitefish, and bluegill (Thorpe 1977). New South Wales, Australia considers *Perca fluviatilis* a noxious fish due to their ability to eliminate other fish species and for their negative impacts on recreational fisheries (NSW DPI 2012a).

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9

This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
	7

- *European Perch are widespread in the Baltic Sea and tolerate salinities up to 7–10 psu (Privolnev 1970, Lutz 1972).*
- *European Perch tolerate a wide range of temperatures (4-31°C).* The optimal temperature for growth is 23°C. *(Toner and Rougeot 2008)*
- *European Perch tolerate a wide range of environments, but prefer shallow and moderately productive freshwaters (Toner and Rougeot 2008).*
- *European Perch populations in Danish lakes have been negatively affected by eutrophication, with both reduced total perch biomass and average body weight as indicators of reduced growth (Jeppesen et al. 2000).*
- *European Perch survive in a pH range: 7.0 to 7.5 (Froese and Pauly 2015).*

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9
Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
	5

- *European Perch tolerate a wide range of temperatures (4-31°C). The optimal temperature for growth is 23°C (Toner and Rougeot 2008).*
- *Redfin Perch overwinters in the profundal zone at temperatures below 6˚C in Lake Constance, Germany, but experiences depletion of its lipid reserves and high mortality following spring spawning (Eckmann 2004).*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
	8

- *Redfin Perch is carnivorous and feeds on a wide variety of foods ranging from small invertebrates (such as crustaceans, worms, molluscs and insect larvae) to fish (NSW DPI 2012a).*

- *Larvae and small juveniles usually feed on planktonic invertebrates. During first summer, many juveniles move near shores to feed on benthic prey (Froese and Pauly 2015).*

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	0
Unknown	U
	6

- *In large numbers, Redfin Perch can out-compete most other fish species (NSW DPI 2012a).*
- *In Australia,* P. fluviatilis *tends to outcompete native species (Welcomme 1988).*

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
	3

- *The absolute fecundity (number of eggs per female) in perch ranges from 15,000 to 300,000 eggs under natural conditions. During artificial spawning, average absolute and relative fecundity (number of eggs per kg of body weight) was around 40,000 eggs per female and 102,000 eggs per kg of body weight (Toner and Rougeot 2008).*
- *European Perch have adapted well to New Zealand's environment, possessing high fecundity and flexibility in behavior and habitat requirements (Hutchison and Armstrong 1993).*
- *Similar species,* P. flavascens*, has a relative fecundity that ranges from 79-223 eggs/g which is equivalent to 79,000-233,000 eggs/kg (Sheri and Power 1969).*

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
	0

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	9

- *The climate match (USFWS 2014c) was high to medium for the entire United States low matches only occurred in the Desert Southwest. Climate six match indicated that the United States has a high climate match. The range for a high climate match is 0.103 and greater, climate match of* P. fluviatilis *is 0.627 (USFWS 2014c).*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	7

- *Perch populations in Danish lakes have been negatively affected by eutrophication, with both reduced total perch biomass and average body weight as indicators of reduced growth (Jeppesen et al. 2000).*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0
Unknown	U
	9

- *This species inhabits a very wide range of habitats from estuarine lagoons, lakes of all types to medium- sized streams. Feeding larvae occur in open water (Froese and Pauly 2015).*
- *European Perch tolerate a wide range of environments, but prefer shallow and moderately productive freshwaters. This is a freshwater species, but because of its euryhaline tolerance, perch is also present in brackish water in the Baltic Sea. Perch prefer lentic river conditions (with a low flow rate) and are also present in deep lakes, up to 40m in depth (Toner and Rougeot 2008).*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0
Unknown	U
	6

- *European Perch tolerate a wide range of temperatures (4-31°C). The optimal temperature for growth is 23°C (Toner and Rougeot 2008).*
- *European Perch tolerate a wide range of environments, but prefer shallow and moderately productive freshwaters (Toner and Rougeot 2008).*
- *European Perch are widespread in the Baltic Sea and tolerate salinities up to 7–10 psu (Privolnev 1970, Lutz 1972).*
- *It is predicted by Lehtonen (1996) that increased temperatures due to climate change will result in* Perca fluviatilis *spawning later in autumn and hatching earlier. In addition, it is expected that larvae will be smaller and will be more vulnerable to possible predators. Juveniles are predicted to grow to a larger size after their first summer due to warmer water temperatures.*

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
	9

- *Redfin Perch are carnivorous and feed on a wide variety of foods ranging from small invertebrates (such as crustaceans, worms, molluscs and insect larvae) to fish (NSW DPI 2012a).*
- *Larvae and small juveniles usually feed on planktonic invertebrates. During first summer, many juveniles move near shores to feed on benthic prey (Froese and Pauly 2015).*
- *In general the smallest perch feed upon plankton Crustacea, the middle-sized ones upon insect larvae and other bottom-living forms, while the largest perch feed chiefly on small fish (Allen 1935).*

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Great Lakes and is not likely to be introduced	-80% total points (at end)
Unknown	U
	9

- *The Redfin Perch has no required species.*

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes)	6
Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0
Unknown	U
	0

- *There is no introduced species in the Great Lakes known to facilitate redfin perch establishment.*
- Gymnocephalus cernua *is established in the Great Lakes and competes with* Perca fluviatilis *where they occur sympatrically (Erkmann 2004, Schleuter 2007).*

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0
Unknown	U
	0

- *The Redfin Perch is unlikely to be preferentially targeted as the prey of Great Lakes species.*

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9

Frequent, moderate inocula	6
Frequent, small inocula OR infrequent, large inocula	3
Infrequent, small or moderate inocula	0
Unknown	U
	U

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
	9

- *Its native range is throughout much of Europe, but it has been introduced to a number of countries around the world as a sport fish (GISD 2012).*
- Perca fluviatilis *is introduced to Australia, China, Cyprus, Italy, Morocco, New Zealand, Spain and South Africa (Papasissi 2013). The species is not a true native of Ireland (although it was introduced hundreds of years ago) and it is still absent from parts of Scotland (USFWS 2014c).*

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
	8

- *Redfin was recorded as eliminating 20,000 newly released Rainbow Trout fry from a reservoir in south-western Australia in less than 72 hours. Redfin are capable of rapidly populating new waterways and in stable water bodies (such as lakes and dams) they can form very dense populations (NSW DPI 2012a).*
- *Kolar and Lodge (2002) developed models that predicted that* Perca fluviatilis *has a high risk for establishment, will spread quickly, and will be a nuisance in the Great Lakes.*

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing the establishment and spread of this species)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent the establishment and/or spread of this species	0
Unknown	U
	0

Establishment Potential Scorecard				
Points	**Probability for Establishment**	A. Total Points (pre-adjustment)		95
>100	High	**Adjustments**		
		B. Critical species	A*(1- 0%)	95
51-99	Moderate	C. Natural enemy	B*(1- 0%)	95
		Control measures	C*(1- 0%)	95
0-50	Low	**Potential for Establishment**		Moderate
# of questions answered as "unable to determine"	**Confidence Level**			
0-1	High	Total # of questions unknown		1
2-5	Moderate			
6-9	Low	Confidence Level		High
>9	Very low			

Section C: Potential for Impact

IMPACT POTENTIAL RESULTS

Environmental: High

Socio-Economic: Moderate

Beneficial: High

***Perca fluviatilis* has the potential for high environmental impact if introduced to the Great Lakes.**

Perca fluviatilis is a carrier of the epizootic haematopoeitic necrosis (EHN) virus. In Australia, the EHN virus carried by *Perca fluviatilis* may have resulted in declines of the native Macquarie Perch, Silver Perch, Murray Cod, and Mountain Galaxias (Lintermans 1991, NSW DPI 2012a).

Perca fluviatilis can potentially compete with native species for zooplankton, macroinvertebrates, and fish (Closs et al. 2003). *Perca fluviatilis* is said to compete for food and space with the Murray Cod (*Maccullochella peelii peelii*) and Golden Perch (*Macquaria ambigua*) (Lintermans et al. 1990). In New Zealand, *Perca fluviatilis* suppressed populations of a native fish, the Common Bully, by direct predation (Closs et al. 2003). Physical removal of *Perca fluviatilis* from ponds resulted in an increased abundance of the common bully. It has been suggested that *Perca fluviatilis* competition is responsible for the local extinction of the rare Mud Minnow, *Galaxiella munda* (USFWS 2014c). It has been reported that *Perca fluviatilis* preyed on native Pygmy Perch (*Edlia vittata*) in Australia, negatively impacting their populations (Arthington and McKenzie 1997). It is suspected that *Perca fluviatilis* negatively affects native fish populations by preying on vulnerable Ewen's Pygmy Perch, *Nanoperca variegata*, vulnerable Yarra Pygmy Perch, *Edelia obscura*, the vulnerable Dwarf Galaxia, *Galaxias pusilla*, and juveniles of Macquarie Perch, *Macquaria australasica* (Wager and Jackson 1993).

It is unknown if *Perca fluviatilis* affects native populations genetically, water quality, or the physical components of the ecosystem.

***Perca fluviatilis* has the potential for moderate socio-economic impact if introduced to the Great Lakes.**

Perca fluviatilis may prey on native species and trout, negatively affecting recreational fisheries. Within a 72-hour period, *Perca fluviatilis* eliminated 20,000 newly released Rainbow Trout fry from a reservoir in south-western Australia (NSW DPI 2012a).

***Perca fluviatilis* has the potential for high beneficial impact if introduced to the Great Lakes.**

Perca fluviatilis is valued as an important fish species for aquaculture, fisheries, and recreation (Setälä et al. 1996, Toner and Rougeot 2008, USFWS 2014c). This species is not known as a biological control agent, does not increase water quality, or have a positive ecological impact. It is not valuable for medical research.

POTENTIAL ENVIRONMENTAL IMPACT

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6 √
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1

Not significantly	0
Unknown	U

- *One of the most significant threats to native fish from Redfin is their potential to spread the viral disease Epizootic Haematopoietic Necrosis (EHN). This disease, which was first isolated in 1985 and is unique to Australia, can cause mass mortality in juvenile redfin perch during the summer months. A number of native species, including Silver Perch, Murray Cod, Mountain Galaxias and particularly Macquarie Perch, are highly susceptible to the disease, and EHN virus may be one factor responsible for the decline in various native species over the last couple of decades (NSW DPI 2012a).*
- P.fluviatilis *can destroy recreational fisheries in enclosed waters by building up large numbers of stunted fish and eliminating other species, and can devastate native fish populations by carrying the epizootic haematopoietic necrosis (EHN) virus (NSW DPI 2012a).*
- *In the Australian Capital Territory, mass mortality of juvenile perch has been attributed to EHN virus, and it is considered likely that this disease has been responsible for major declines in populations of Macquarie Perch in this region (Lintermans 1991). A chronic form of EHN virus with a lower mortality also occurs in farmed Rainbow Trout (Langdon and Humphrey 1987).*

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6 √
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1
Not significantly	0
Unknown	U

- *In such large numbers,* P.fluviatilis *can also out-compete most other fish species (NSW DPI 2012a).*
- Perca fluviatilis *was introduced to Lake Bositen, Xinjiang in the 1970's and caused the disappearance of endemic fish Asipiorhynchus laticeps from the lake. This species was introduced from the Ertrix River basin in the north Xiangjiang Autonomous Region to the Bosten Lake in the south Xiangjiang autonomous regions for fish resource enhancement purpose. It became a dominant fish in the new environment (Bartley 2006, Froese and Pauly 2015).*
- *This species has been implicated in the local extinction of the rare Mud Minnow, Galaxiella Munda, (Wager 1996), as well as affecting the recruitment of a recreationally important decapod (*Cherax cainii*) (USFWS 2014c).*
- *Adverse interactions, in the form of food competition and possibly predation, by the redfin on the 'endangered' trout cod,* Maccullochella macquariensis, *are said to have contributed to the cod's decline (Wager and Jackson 1993).*
- *In New South Wales, the redfin is regarded as a significant predator on indigenous fishes, and juveniles probably compete with small planktivorous fishes for food (P. Gehrke, pers. comm., cited in Arthington and McKenzie 1997).*

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in the food web)	6 √
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR	1

Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	
Not significantly	0
Unknown	U

- P.fluviatilis *has been implicated in the local extinction of the rare Mud Minnow,* Galaxiella munda *(Wager 1996).*
- *The Redfin is suspected of predation on the 'vulnerable' Ewen's Pygmy Perch,* Nannoperca variegata*, and the 'vulnerable' Yarra Pygmy Perch,* Edelia obscura*, the 'vulnerable' Dwarf Galaxias,* Galaxias pusilla*, and juveniles of the 'poorly known' Macquarie Perch,* Macquaria australasica *(Wager and Jackson 1993). Adverse interactions, in the form of food competition and possibly predation, by the Redfin on the 'endangered' trout cod,* Maccullochella macquariensis*, are said to have contributed to the cod's decline (Wager and Jackson 1993).*
- *In New South Wales, the Redfin is regarded as a significant predator on indigenous fishes, and juveniles probably compete with small planktivorous fishes for food (P. Gehrke, pers. comm., as cited in Arthington and McKenzie 1997).*

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0
Unknown	U √

- *The biggest threat would likely be to native perch,* Perca flavescens*, via competition and hybridization (USEPA 2008).*
- Perca flavescens *is able to hybridize with introduced ruffe (*Gymnocephalus cernua*) (Crosier et al. 2007).*

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1
Not significantly	0
Unknown	U √

E6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem	6

AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1
Not significantly	0 √
Unknown	U

- *In New South Wales, the Redfin Perch has not been linked with large-scale ecological degradation (P. Gehrke, pers. comm., as cited in Arthington and McKenzie 1997).*

Environmental Impact Total	**18**
Total Unknowns (U)	**2**

Scoring		
Score	# U	**Impact**
>5	Any	<u>**High**</u>
2-5	Any	Moderate
0	0-1	Low
1	0	
0	≥2	Unknown
1	≥1	

<u>POTENTIAL SOCIO-ECONOMIC IMPACT</u>

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1
Not significantly	0 √
Unknown	U

S2) Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6

Yes, but the costs have been small and are largely reparable or preventable	1
Not significantly	0 √
Unknown	U

S3) Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0 √
Unknown	U

S4) Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1 √
Not significantly	0
Unknown	U

- *Redfin Perch predation can seriously impact populations of native species, and can also affect recreational fisheries for these species. For example, Redfin was recorded as eliminating 20,000 newly released Rainbow Trout fry from a reservoir in south-western Australia in less than 72 hours (NPW DPI 2012).*

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6
Yes, but negative consequences have been small	1 √
Not significantly	0
Unknown	U

- *Redfin Perch predation can seriously impact populations of native species, and can also affect recreational fisheries for these species. For example, Redfin was recorded as eliminating 20,000 newly released Rainbow Trout fry from a reservoir in south-western Australia in less than 72 hours (NPW DPI 2012).*

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

Socio-Economic Impact Total	**2**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	**Moderate**
0	0-1	Low
1	0	
0	≥2	Unknown
1	≥1	

POTENTIAL BENEFICIAL EFFECT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular effect. An "Unknown" response is appropriate if the potential for a particular effect might be inferred but has not been explicitly reported or if there is an unresolved debate about a particular effect.

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1
Not significantly	0 √
Unknown	U

B2) Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?

Yes, it is economically important to at least one of these industries	6 √
Yes, but its economic contribution is small	1
Not significantly	0
Unknown	U

- Perca flavescens *is valuale for fisheries: highly commercial; aquaculture: commercial; and for gamefish (Froese and Pauly 2015).*
- *The total catch of Redfin Perch in Finland was about 20,000 tonnes in 1992. 96 % of it was harvested by recreational fishermen, and 70% from inland waters. Only 2% (242 tonnes) of the total inland catches was harvested in the commercial fisheries (Karttunen 1994, Leinonen 1993, Tuunainen 1994).*
- *Commercial inland fishing in Finland is mostly based on vendace (*Coregonus albula *L.). There are strong fluctuations in the vendace stocks. When the density of the stock is low, fishermen seek alternative species that could be profitably harvested. The main proportion of Redfin Perch is caught during the spawning season in*

May to June. During this period, perch may significantly contribute to the professional fishing, particularly since vendace catches are low in spring (Setälä et al. 1996).

B3) Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local communities and/or tourism	6 √
It is sometimes employed recreationally, but adds little value to local communities or tourism	1
Not significantly	0
Unknown	U

- *The European Perch or Redfin,* Perca fluviatilis*, was introduced into Tasmania in 1862 and into Victoria in 1868 as a sport and table fish (Arthington and McKenzie 1997).*
- *In fisheries this species is highly commercial, used for aquaculture, and as a gamefish (Froese and Pauly 2015).*
- Perca flavescens *is a popular sport fish with some anglers because of its fighting qualities and taste (NSW DPI 2012a).*

B4) Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR It is potentially important to medicine or research and is currently being or scheduled to be studied	1
Not significantly	0 √
Unknown	U

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1
Not significantly	0 √
Unknown	U

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1

Not significantly	0 √
Unknown	U

Beneficial Effect Total	**12**
Total Unknowns (U)	**0**

Scoring		
Score	# U	**Impact**
>5	Any	**<u>High</u>**
2-5	Any	Moderate
0	0-1	Low
1	0	
0	≥2	Unknown
1	≥1	

Scientific Name: *Perccottus glenii*
Dybowski, 1877

Common Name: Amur Sleeper

Synonyms: Chinese Sleeper, Rotan, *Eleotris dybowskii* (Herzenstein & Warpachowski, 1888), E*leotris pleskei* (Warpachowski, 1888), *Perccottus glehni*, *Perccottus pleskei* (Warpachowski, 1888)

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: Unlikely

Hitchhiking/fouling: Unlikely

Unauthorized intentional release: Low

Stocking/planting/escape from recreational culture: Unlikely

Escape from commercial culture: Unlikely

Transoceanic shipping: Moderate

***Perccottus glenii* has a moderate probability of introduction to the Great Lakes (Confidence level: High).**

Potential pathway(s) of introduction: Unauthorized Intetional Release,Transoceanic Shipping (ballast water)

Perccottus glenii does not currently occur near waters connected to the Great Lakes basin. This species is not known to hitchhike or foul recreational gear. *Perccottus glenii* is sold in Eurasia and was once a popular fish for aquariums and backyard ponds (Reshetnikov 2004). It is used as bait fish in Europe (Edgar and Bird 2005, Reshetnikov 2004). There is no evidence that this species can be obtained in North America to be released into the Great Lakes. *Perccottus glenii* is not cultured or stocked in the Great Lakes region. This species occurs in ports that have direct trade connections with the Great Lakes, such as those in the Baltic Sea (Koščo et al. 2003, NBIC 2009). One of the suggested pathways for the introduction of *Perccottus glenii* is ballast water (Ćaleta et al. 2010). *Perccottus glenii* can tolerate a broad range of temperatures (Golovanov and Ruchin 2011) and waters with low oxygen (Koščo et al. 2008, Reshetnikov 2003). Its tolerance to high salinity is not fully known, but it is likely that ballast regulations will substantially impact the survival of *Perccottus glenii*.

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100
No, this species does not occur near waters connected to the Great Lakes basin and/or is not mobile or able to be transported by wind or water.	0 √
Unknown	U

- Perccottus glenii *first appeared outside of its native habitat, the Amur River basin, China (Koščo et al. 2008) in Moscow in 1912. Since then,* P. glenii *has spread 100° East and West to Poland, Slovakia, Hungary, Bulgaria, Romania, Serbia, Croatia, Moldova and other countries (Reshetnikov 2012).*
- *There has been no mention of species ever being found in North America.*
- Perccottus glenii *travels via connecting waters (Koščo et al. 2010)*
- *Long term ranges of* P. glenii *depend on climate variations however, as opposed to open borders (Reshetnikov and Ficetola 2011)*
- *No geographical barriers exist between the regions of Eastern Europe that have currently been inhabited and potential habitats in Western Europe (Reshetnikov 2012).*
- *Long term ranges will depend on climate variations however, as opposed to open borders (Reshetnikov and Ficetola 2011).*

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0 √
Unknown	U

- Perccottus glenii *occasionally travels with stocking carp from fish farms in China to other parts of Europe, however there was no mention of any natural or anthropogenic products that resulted in a transfer to the Great Lakes region (Reshetnikov 2004).*
- *There has been no mention of species being found in North America.*

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a) Is this species sold at aquarium/pet/garden stores ("brick & mortar" or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100 √
No, this species this species is rarely/never sold.	0
Unknown	U

Perccottus glenii *is sold in Eurasia and was at one point a popular fish for use in aquariums and backyard ponds (Reshetnikov 2004).*
Perccottus glenii *is often used as bait fish, including Europe (Edgar and Bird 2005, Reshetnikov 2004).*

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1 √
Unknown	U

- *There has been no record of* P. glenii *being sold in North America.*

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0 √
Unknown	U

- Perccottus glenii *is sold in Eurasia and was at one point a popular fish for use in aquariums and backyard ponds in Russia (Reshetnikov 2004)*
- *Small introductions in Eurasia were attempted in an effort to reduce mosquito populations with no significant results (Koščo et al. 2003)*

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is likely to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces), this activity may occur within 20 km of the basin because of the species' popularity/value.	Score x 0.25
Unknown	U

- *There has been no record of* P. glenii *being used to stock in North America*

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100
No, this species is not commercially cultured in or transported through the Great Lakes region.	0 √
Unknown	U

- *There has been no record of* P. glenii *being transported through the Great Lakes region.*

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80 √
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40
No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0
Unknown	U

- Perccottus glenii *tolerates very low temperatures as well as relatively high temperatures, from lakes that nearly freeze solid to a maximum temperature of approximately 38.2-35.5°C (Golovanov and Ruchin 2011).*
- *According to Ćaleta et al. (2010), ballast water is a possibility for introductions into new places, however has not been observed.*

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5 √
Yes, but this species has neither been observed in ballast/fouling ships entering the Great Lakes nor in ports in direct trade with the Great Lakes.	Score x 0.1
No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0
Unknown	U

- Perccottus glenii is *found in the Gulf of Finland (Koščo et al. 2003) which has trade relations in the Great Lakes.*

Vector Potential Scorecard				
Vector	**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind	**0**	x	**0**	Unlikely
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.	**0**	x	**0**	Unlikely
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)	**100**	x 0.1	**10**	Low
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)	**0**	x	**0**	Unlikely
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)	**0**	x	**0**	Unlikely
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling	**80**	x 0.5	**40**	Moderate
Total Unknowns (U)	**0**	**Confidence Level**	High	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

<u>ESTABLISHMENT POTENTIAL RESULTS</u>

Status: **Established in North America, but not including the Great Lakes.**

***Perccottus glenii* has a high probability of establishment if introduced to the Great Lakes (Confidence level: High).**

The native and introduced ranges have a similar climate to the Great Lakes region and Mountain West (USFWS 2014a). *Perccottus glenii* can tolerate a wide range of water temperatures (Golovanov and Ruchin 2011, Verreycken 2013). Several studies mention that this species can tolerate low dissolved oxygen levels (Ćaleta et al. 2010, Koščo et al. 2008, Reshetnikov 2003, Yang et al. 2012), but no specific ranges are reported. The optimal salinity for this species is 0-6 ppt (Golovanov and Ruchin 2011) and it inhabits fresh to brackish water (Froese and Pauly 2015). *Perccottus glenii* is also resistant to high water eutrophication (Koščo et al. 2003). Given its tolerances to a wide variety of environmental conditions, it is likely that this species can establish in the Great Lakes, especially in stagnant water bodies of a shallow depth. This species is known to overwinter under frozen bodies of water, and hibernates in mud (Golovanov and Ruchin 2011, Koščo et al. 2008, USFWS 2014a), thus it is likely that this species can overwinter in the Great Lakes. *Perccottus glenii* will likely adapt to the effects of climate change in the Great Lakes, including warmer water temperatures, shorter duration of ice cover, and increased salinization.

Perccottus glenii feeds opportunistically, preying on animals at every trophic level, and is omnivorous (Koščo et al. 2008, Grabowska et al. 2009, Reshetnikov 2003). This species has the potential to compete with native species (Koščo et al. 2003, Orlova et al. 2006, Reshetnikov 2003). In addition, there are species in the Great Lakes region that may prey on *Perccottus glenii* such as perch and pike (Golovanov and Ruchin 2011), but little research has been conducted to investigate whether these predators will reduce this species' probability of establishment.

Its average fecundity ranges 7,766-9,149 per female, which increases with increasing size (Grabowska et al. 2011). The fecundity of *Perccottus glenii* is higher than that of native nest-guarders, but lower than fishes not exhibiting parental care. This species is characterized by early maturation and reproduction where it has been introduced, which may aid its establishment into new areas. Individual growth rates are higher in the Vistula River than in its native range (Grabowska et al. 2011).

Historically, this species has established populations extensively outside of its native range. Its nonindigenous range includes western Russia (Grabowska et al. 2011, Reshetnikov 2003), Latvia (USFWS 2014a), Poland (Grabowska et al. 2011), Ukraine (Kutsokon et al. 2014, Kvach 2012), eastern Slovakia (Koščo et al. 2003), Hungary (Reshetnikov 2004), Romania (USFWS 2014a), Bulgaria (Jurajda et al. 2005), Serbia (Simonović et al. 2006), Croatia (Ćaleta et al. 2010), and Germany (Reshetnikov and Schliewen 2013).

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6

This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
	8

- Perccottus glenii *tolerates a wide range of conditions (Reshetnikov 2004).*
- P. glenii *has an extremely high tolerance to unfavorable conditions (Golovanov and Ruchin 2011).*
- P. glenii *is very tolerant to high temperatures up to 38.2-35.5°C and is one of the most resistant fish to freezing (Golovanov and Ruchin 2011).*
- *Optimal conditions for* P.glenii *are in stagnant, muddy, littoral waters (Grabowska et al. 2011)*
- P. glenii *can withstand very low oxygen levels (Koščo et al. 2008), to 0.1 mg/L (Grabowska 2011).*
- P. glenii *lives in both fresh and brackish water (Froese and Pauly 2015).*
- *The optimal salinity for this species is 0-6 ppt (Golovanov and Ruchin 2011).*
- *It can tolerate temperatures as low as 1°C (Verreycken 2013) to as high as 35.8°C (Golovanov et al. 2013).*

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9
Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
	9

- Perccottus glenii *is one of the most resistant fish to freezing (Golovanov and Ruchin 2011).*
- P. glenii *burrows into the mud and hibernates if the water body is completely frozen or dried out (USFWS 2014a).*
- P. glenii *can withstand very low oxygen levels (Koščo et al. 2008), to 0.1 mg/L (Grabowska 2011).*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
	9

- *The diet of* P. glenii's *main diet is wide. The diet includes chironomid larvae, caddisflies, dragonflies, mollusks, tadpoles, juvenile fish, fish eggs, higher aquatic plants (Golovanov and Ruchin 2011).*
- *This species is a non-selective opportunistic predator (Grabowska et al. 2009).*
- *This species is considered a switch predator (Grabowska et al. 2009).*

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	0
Unknown	U
	6

- Perccottus glenii *is able to dramatically decrease species diversity in some areas, occasionally completely ridding them of amphibian species (Reshetnikov and Ficetola 2011).*
- *Highest growth rates are seen in places where the fish has been introduced as opposed to native ranges (Grabowska et al. 2011).*
- Perccottus glenii *can very much affect population dynamics of aquatic ecosystems (Grabowska et al. 2009).*
- *Reshetnikov (2003) suggests that competition may be a factor in reducing the populations of fish and amphibians, but primarily attributes this to direct predation.*

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
	3

- *Lower growth levels for older age classes have been reported for* P. glenii *(Grabowska et al. 2011); however, introduced populations have elevated fecundity (Welcomme 1988).*
- *This species average fecundity ranges 7,766-9,149 per female, which increases with increasing size (Grabowska et al. 2011).*
- *Its fecundity is higher than that of native nest-guarders, but is lower than fishes no exhibiting parental care (Grabowska et al. 2011).*

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes	9

based on these attributes)	
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
	5

- Perccottus glenii *matures and reproduces early in life (Grabowska et al. 2011).*
- *Males protect the eggs and pelagic larvae (Kottelat and Freyhof 2007).*
- *The highest growth rates often occur right after introduction (Grabowska et al. 2011).*

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- *The climate of Western Europe is similar but not exact to that of the Great Lakes region.*
- *The USFWS's Ecological Risk Screening Summary (2014a) predicted a high climate match throughout the Great Lakes.*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- Perccottus glenii *invades a vast area, where a wide variety of abiotic factors are seen. Therefore,* P. glenii *will probably be able to tolerate most of the Great Lakes conditions, not because they are optimal, but because its tolerance range is so large (Reshetnikov 2004).*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0
Unknown	U
	7

- Perccottus glenii *is restricted to shallow waters, not usually found at depths deeper than 10m (Pronin and Bolonev 2006).*
- *This species spreads best through lentic bodies of water (Golovanov and Ruchin 2011).*
- P. glenii *is found near coasts and in vegetation (Golovanov and Ruchin 2011).*
- P. glenii *optimal conditions are stagnant muddy waters (Grabowska et al. 2009)*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0
Unknown	U
	9

- Perccottus glenii *has extreme tolerance to unfavorable conditions (Golovanov and Ruchin 2011).*
- *This species is very tolerant to high temperatures up to 38.2-35.5°C and is one of the most resistant fish to freezing (Golovanov and Ruchin 2011).*
- P. glenii *can withstand very low oxygen levels (Koščo et al. 2008), to 0.1 mg/L (Grabowska 2011).*
- P. glenii *lives in both fresh and brackish water (Froese and Pauly 2015).*

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
	9

- Perccottus glenii's *main diet is wide. The diet includes chironomid larvae, caddisflies, dragonflies, mollusks, tadpoles, juvenile fish, fish eggs, and higher aquatic plants (Golovanov 2013).*
- *The fish is a non-selective opportunistic predator (Grabowska et al. 2009).*
- *The fish is considered a switch predator (Grabowska et al. 2009).*
- Perccottus glenii *feeds opportunistically, preying on animals at every trophic level, and is omnivorous (Koščo et al. 2008, Grabowska et al. 2009, Reshetnikov 2003).*

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Great Lakes and is not likely to be introduced	-80% total points (at end)
Unknown	U
	9

- *No required critical species requirements were found in the research for this species.*

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of	9

this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes)	6
Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0
Unknown	U
	0

- *No species were found to likely aid in this species establishment or spread were found in the research.*

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0
Unknown	U
	-5%

- *Potential predators could possibly be perch and pike, but there is very little research on this possibility (Golovanov and Ruchin 2011).*

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9
Frequent, moderate inocula	6

Frequent, small inocula OR infrequent, large inocula	3
Infrequent, small or moderate inocula	0
Unknown	U
	U

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
	9

- Perccottus glenii *has been able to spread over 100° East and West of its introduced region (Reshetnikov 2012)*
- *A very high risk of future invasion within fitting climates exists in Europe (Reshetnikov and Ficetola 2011).*
- *This species nonindigenous range includes western Russia (Grabowska et al. 2011, Reshetnikov 2003), Latvia (USFWS 2014a), Poland (Grabowska et al. 2011), Ukraine (Kutsokon et al. 2014, Kvach 2012), eastern Slovakia (Koščo et al. 2003), Hungary (Reshetnikov 2004), Romania (USFWS 2014a), Bulgaria (Jurajda et al. 2005), Serbia (Simonovic et al. 2006), Croatia (Ćaleta et al. 2010), and Germany (Reshetnikov and Schliewen 2013).*

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
	9

- *Since 1912*, P. glenii *has been able to spread over 100° East and West of the introduction site to 15 countries (Reshetnikov 2012).*
- *Considered as one of the most widespread (Reshetnikov 2010) and successful fish invaders in European inland waters of the last decades (Copp et al. 2005).*

- *The rate of the Amur Sleeper expansion is impressive - the rate of its expansion in the Vistula River ranged from an initial 44 km per year, up to 197 km per year thereafter (mean ~ 88 km per year) (Grabowska 2011).*

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing the establishment and spread of this species)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent the establishment and/or spread of this species	0
Unknown	U
	0

- *No controls methods were found in an effort to prevent the establishment of* P. glenii *in the Great Lakes.*

Establishment Potential Scorecard				
Points	**Probability for Establishment**	A. Total Points (pre-adjustment)		108
>100	High	**Adjustments**		
		B. Critical species	A*(1- 0%)	108
51-99	Moderate	C. Natural enemy	B*(1- 5%)	102.6
		Control measures	C*(1- 0%)	102.6
0-50	Low	**Potential for Establishment**		High
# of questions answered as “unable to determine”	**Confidence Level**			
0-1	High	Total # of questions unknown		1
2-5	Moderate			
6-9	Low	Confidence Level		High
>9	Very low			

Section C: Potential for Impact

IMPACT POTENTIAL RESULTS

Environmental: High

Socio-Economic: Low

Beneficial: Moderate

***Perccottus glenii* has the potential for high environmental impact if introduced to the Great Lakes.**

Perccottus glenii is a host to some parasites. Data suggests that parasites *Myxidium rimskykorsakowi*, *Henneguya alexeevi*, *Nippotaenia mogurndae*, and *Gyrodactylus perccotti* were introduced to new regions with *P. glenii* as a vector (Sokolov et al. 2014); these parasites infect fishes in the Odontobutidae family. The parasite load of this species is more diverse in its introduced ranges than in its native range.

As a trophic competitor and a predator, *Perccottus glenii* has been implicated in the population declines of historically abundant native species such as *Umbra krameri*, *Carassius carassius*, and *Leucapspius delineatus* (Koščo et al. 2003). Habitats with high numbers of *Perccottus glenii* were associated with lower fish species richness and diversity. *Perccottus glenii* can potentially compete with native species that utilize similar microhabitats and food resources (Koščo et al. 2003).

By feeding heavily on macroinvertebrates, larval and adult amphibians, and fish eggs, *Perccottus glenii* has the potential to alter predator-prey relationships (Reshetnikov 2003). Many aquatic larvae of terrestrial organisms are primary consumers and export nitrogen from the system when leaving the water at maturity, which is meaningful for nitrogen dynamics and the rate of eutrophication. *Perccottus glenii* effectively reduces the transport of nitrogen from aquatic to terrestrial environments by feeding on these organisms.

***Perccottus glenii* has the potential for low socio-economic impact if introduced to the Great Lakes.**

Perccottus glenii is a host to the liver fluke, which is a parasite that infects humans (Mastitsky et al. 2010), but there are no reports suggesting that *Perccottus gleniii* is responsible for liver fluke infection in humans. There is no indication that this species impacts water quality, markets, or infrastructure. There is no evidence suggesting that it inhibits recreation or diminishes the natural value of the areas it inhabits.

***Perccottus glenii* has the potential for moderate beneficial impact if introduced to the Great Lakes.**

Small introductions of *Perccottus glenii* in Eurasia were attempted in effort to reduce mosquito populations with no significant results (Koščo et al. 2003). This species can be used as a bait fish and is sometimes kept in ponds or aquariums (Koščo et al. 2008, Reshetnikov 2004). There is no indication that *Perccottus glenii* is valuable for medical research, for removing toxins, or for positively impacting the ecosystem.

POTENTIAL ENVIRONMENTAL IMPACT

NOTE: In this section, a “Not significantly” response should be selected if the species has been studied but there have been no reports of a particular impact. An “Unknown” response is appropriate if the species is poorly studied.

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1 √
Not significantly	0
Unknown	U

- Perccottus glenii *is host to liver fluke as well as an exotic tapeworm (Mastitsky et al. 2010).*
- This species *is a potential transmitter of diseases (Golovanov and Ruchin 2011).*
- P. glenii *transmits parasites Nippotaenia mogundae and Eustrongylides (Ondračková et al. 2012a) Data suggests that parasites* Myxidium rimskykorsakowi*,* Henneguya alexeevi*,* Nippotaenia mogurndae*, and* Gyrodactylus perccotti *were introduced to new regions with* P. glenii *as a vector (Sokolov et al. 2014); these parasites infect fishes in the Odontobutidae family.*

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1 √
Not significantly	0
Unknown	U

- Perccottus glenii *has led to unfavorable feeding relationships between other organisms, slower growth of native species, and prolonged spawning (Golovanov and Ruchin 2011).*
- *This species has been implicated in the decrease in populations of native species Umbra krameri,* Carassius carassius *and* Leucaspius delineatus *which were abundant in the past through competition for identical habitat requirements (Lusk et al. 2004).*
- P. glenii *has partially displaced local species in Tashkent (Welcomme 1988).*
- *This species has displaced several species of native fishes (Solarz 2005).*
- Perccottus glenii *has threatened* Umbra krameri *(European mud minnow), a IUCN Vulnerable species in Slovakia, through competition for resources and predation (Koščo et al. 2008).*

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in the food web)	6 √
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	1

Not significantly	0
Unknown	U

- Perccottus glenii *is a severe threat to the great crested newt,* T. cristatus *(Reshetnikov 2012).*
- *This species has completely eliminated some amphibian species in some areas (Reshetnikov and Ficetola 2011).*
- P. glenii *has threatened* Umbra krameri *(European Mud Minnow), a IUCN "Vulnerable" species in Slovakia, through competition for resources and predation (Koščo et al. 2008).*
- Perccottus glenii *has threatened* Rhynchocypris percnurus *(Lake Minnow), a IUCN "Endangered" species in Poland, through predation (Wolnicki and Kolejko 2008).*

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0
Unknown	U √

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1
Not significantly	0
Unknown	U √

E6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1
Not significantly	0
Unknown	U √

- *While* P. glenii *will eat aquatic plants (Golovanov 2013) and plankton (Koščo et al. 2008), the effect on these communities has not been reported.*

Environmental Impact Total	**8**
Total Unknowns (U)	**3**

Scoring		
Score	# U	**Impact**
>5	Any	**<u>High</u>**
2-5	Any	Moderate
0	0-1	Low
1	0	Low
0	≥2	Unknown
1	≥1	Unknown

<u>POTENTIAL SOCIO-ECONOMIC IMPACT</u>

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1 √
Not significantly	0
Unknown	U

- Perccottus glenii *is a host to liver fluke in humans as well as an exotic tapeworm (Mastitsky et al. 2010).*

S2) Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1
Not significantly	0 √
Unknown	U

S3) Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0 √

Unknown	U

S4) Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

- Perccottus glenii *has been known to be mixed with stocking fish such as carp, but there do not seem to be high impacts on industry (Reshetnikov 2004)*

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

Socio-Economic Impact Total	**1**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**<u>Low</u>**
1	0	

0	≥2	Unknown
1	≥1	

POTENTIAL BENEFICIAL EFFECT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular effect. An "Unknown" response is appropriate if the potential for a particular effect might be inferred but has not been explicitly reported or if there is an unresolved debate about a particular effect.

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1
Not significantly	0
Unknown	U √

- Perccottus glenii *has impacted Crucian Carp (*Carassius carassius*) populations, leading either to reproductive failure (Reshetnikov 2003) or elimination of all individuals less than 40 mm in length (Reshetnikov 2000). While this species had not been introduced to the Great Lakes, it is related to other nonnative cyprinids in the basin's waters (Courtenay 2006).*

B2) Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?

Yes, it is economically important to at least one of these industries	6
Yes, but its economic contribution is small	1 √
Not significantly	0
Unknown	U

- Perccottus glenii *has no positive economic importance (Koščo et al. 2008)*
- *This species is sometimes used as bait fish (Koščo et al. 2008)*

B3) Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local communities and/or tourism	6
It is sometimes employed recreationally, but adds little value to local communities or tourism	1 √
Not significantly	0
Unknown	U

- Perccottus glenii *has no positive economic importance (Koščo et al. 2008)*
- *This species is sometimes used as bait fish (Koščo et al. 2008)*
- P. glenii *is sometimes kept in garden ponds or aquariums (Reshetnikov 2004)*

B4) Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR It is potentially important to medicine or research and is currently being or scheduled to be studied	1
Not significantly	0 √
Unknown	U

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1
Not significantly	0 √
Unknown	U

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1
Not significantly	0 √
Unknown	U

Beneficial Effect Total	**2**
Total Unknowns (U)	**1**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	**<u>Moderate</u>**
0	0-1	Low
1	0	
0	≥2	Unknown
1	≥1	

Scientific Name: *Phoxinus phoxinus*
Linnaeus, 1758

Common Name: Eurasian Minnow

Synonyms: Common Minnow, *Cyprinus aphya*, *Cyprinus chrysoprasius*, *Cyprinus galian*, *Cyprinus isetensis*, *Cyprinus lumaireul*, *Cyprinus morella*, *Cyprinus phoxinus*, *Cyprinus rivularis*, *Leuciscus phoxinus*, *Phoxinus csikii*, *Phoxinus laevis*, *Phoxinus marsilii*, *Phoxinus rivularis*, *Phoxinus varius*, *Phoxynus montanus*, *Salmo rivularis*

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: Unlikely

Hitchhiking/fouling: Unlikely

Unauthorized intentional release: Unlikely

Stocking/planting/escape from recreational culture: Unlikely

Escape from commercial culture: Unlikely

Transoceanic shipping: Moderate

***Phoxinus phoxinus* has a moderate probability of introduction to the Great Lakes (Confidence level: High).**

Potential pathway(s) of introduction: Transoceanic Shipping (ballast water)

Phoxinus phoxinus may be able to be taken up in ballast water and survive ballast tank environments. This species is capable of surviving over two weeks without food (Russell and Wootton 1992), and can tolerate a wide range of temperatures (Frost 1943, Thorman 1986) and moderately low dissolved oxygen levels (Jones 1952). However, current ballast regulations may substantially impact its survival. *Phoxinus phoxinus* occurs in ports that have direct trade connections with the Great Lakes (Hesthagen and Sandlund 2010, NBIC 2009).

Phoxinus phoxinus does not currently occur near waters connected to the Great Lakes. This species is not known to hitchhike or foul recreational gear. It is not cultured, stocked, or sold in the Great Lakes region.

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100
No, this species does not occur near waters connected to the Great Lakes basin and/or is not mobile or able to be transported by wind or water.	0 √
Unknown	U

- *The distribution of the species is currently limited to Europe (Froese and Pauly 2015, USEPA 2008).*

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0 √
Unknown	U

- *The distribution of the species is currently limited to Europe (Froese and Pauly 2015, USEPA 2008).*

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a) Is this species sold at aquarium/pet/garden stores ("brick & mortar" or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100
No, this species this species is rarely/never sold.	0 √
Unknown	U

- Phoxinus phoxinus *is commonly used as bait in Europe but not in North America (Kolar and Lodge 2002, Museth et al. 2007).*

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0 √
Unknown	U

- *There has been no record of use in North America*.

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is likely to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces), this activity may occur within 20 km of the basin because of the species' popularity/value.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100
No, this species is not commercially cultured in or transported through the Great Lakes region.	0 √
Unknown	U

- *There has been no record of use in North America.*

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80 √
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40
No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0
Unknown	U

- Phoxinus phoxinus *can survive more than two weeks without food with little to no adverse effects on long-term viability (Russell and Wootton 1992).*
- *Some brackish or freshwater species have been found to be able to persist in ballast tanks even after open ocean exchange due to retention of some of the fresh water within the tanks (Ricciardi and MacIsaac 2000), but current regulations are likely to substantially impact survival.*

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5 √
Yes, but this species has neither been observed in ballast/fouling ships entering the Great Lakes nor in ports in direct trade with the Great Lakes.	Score x 0.1
No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0
Unknown	U

- Phoxinus phoxinus *is found throughout Europe and is endemic in the Ponto-Caspian region (Kolar and Lodge 2002, USEPA 2008).*
- Phoxinus phoxinus *occurs in the Baltic Sea (Hesthagen and Sandlund 2010).*

Vector Potential Scorecard					
Vector		**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind		**0**	x	**0**	Unlikely
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.		**0**	x	**0**	Unlikely
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)		**0**	x	**0**	Unlikely
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)		**0**	x	**0**	Unlikely
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)		**0**	x	**0**	Unlikely
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling		**80**	x 0.5	**40**	Moderate
Total Unknowns (U)	**0**	**Confidence Level**		High	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely

# of Unknowns (overall)	Confidence Level
0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

ESTABLISHMENT POTENTIAL RESULTS

Status: **Established in North America, but not including the Great Lakes.**

***Phoxinus phoxinus* has a moderate probability of establishment if introduced to the Great Lakes (Confidence level: High).**

The Great Lakes climate is similar to the current range of *Phoxinus phoxinus* (USFWS 2014b). *Phoxinus phoxinus* can tolerate a broad range of temperatures and moderately low oxygen levels. This species occurs in the southern Bothnian Sea, Sweden, which has ice cover for about 4-5 months (Thorman 1986); thus it is likely that it is capable of overwintering in the Great Lakes. This species inhabits littoral zones with gravel and rocky bottoms (Museth et al. 2002), which are habitats that are available in the Great Lakes basin. Due to its broad physiological tolerance, *Phoxinus phoxinus* will likely be able to adapt to the effects of climate change in the Great Lakes. As an omnivorous fish with a broad diet, *P. phoxinus* is likely able to find an appropriate food source in the Great Lakes. It has been suggested by Borgstrøm et al. (2010) that introduced *P. phoxinus* competes with brown trout for prey, causing reduced brown trout recruitment and individual growth rates. The fecundity of *Phoxinus phoxinus* ranges from 200-1,000 eggs per female (Museth et al. 2002), which is slightly lower than the fecundity of *P. cumberlandensis* of 1,540 eggs per female (Starnes and Starnes 1981).

After its introduction to Lake Øvre Heimdalsvatn in the 1960s, it was heavily preyed on by Brown Trout (Museth et al. 2003). Brown Trout currently occurs in the Great Lakes and is non-native (Baker and Li 2015b), but it is unknown whether it will prevent the establishment of *P. phoxinus* in the Great Lakes. Its distribution has spread primarily by anglers (Museth et al. 2007). In Norway, its spread was limited to the southeast during the early 1900s, but by the 1950s, translocations of *P. phoxinus* had become frequent. In Lake Øvre Heimdalsvatn, *P. phoxinus* were first observed in 1969 and spread to the whole lake by 1985 (Naestad and Brittain 2010). *Phoxinus phoxinus* has also spread by unintentional introduction with the stocking of hatchery-reared brown trout, and by dispersal downstream from upstream reservoirs (Museth et al. 2007).

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive	6

in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
	7

- Phoxinus phoxinus *has been documented in a wide range of habitats with diverse conditions, including varied pH, nutrients, temperatures, and depths (Frost 1943, Hesthagen and Sandlund 2010).*
- *Temperature tolerance for this species ranges from 2°C to 20°C (Riehl and Baensch 1991).*
- Phoxinus phoxinus *is found in a wide range of cold and well oxygenated habitats from small, fast-flowing streams to large Nordic lowland river, in addition to small upland lakes to large oligotrophic lakes (Froese and Pauly 2015).*
- *This species is found in salinities up to 6 ppt (Thorman 1986).*
- *It occurs in waters that have ice cover over the winter and have been recorded in waters with temperatures up to 31°C (Frost 1943).*
- *Experiments by Jones (1952) suggest that this species does not react to waters 4-6 mg/L O_2, but does produce a reaction below those dissolved oxygen levels.*

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9
Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
	8

- *The distribution of European Minnows has been documented in Arctic streams and English ponds (Frost 1943, Mills 1988).*
- *Temperature tolerance for this species ranges from 2°C to 20°C (Riehl and Baensch 1991).*
- Phoxinus phoxinus *overwinters in coarse substrate or in deep pools with low current (Kottelat and Freyhof 2007).*
- *This species occurs in the southern Bothnian Sea, Sweden, which has ice cover for about 4-5 months (Thorman 1986).*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0

Unknown	U
	9

- *The diet of* P. phoxinus *has been shown to vary among chironimids, amphipods, EPT taxa, cladocerans, terrestrial invertebrates, etc. and has been shown to shift in preference among these with competitive pressure from brown trout (Museth et al. 2010, Oscoz et al. 2006).*
- Phoxinus phoxinus *feeds on algae, plant debris in rivers, mollusks, crustaceans and insects (Billard 1997).*
- Phoxinus phoxinus *feeds on zooplankton, aquatic and terrestrial macroinvertebrates, mollusks, and plant material (Frost 1943).*

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	0
Unknown	U
	7

- *There is evidence of diet overlap between Brown Trout and European Minnows, with mixed evidence of competitive exclusion. Coexistence has been demonstrated through diet shifts (Museth et al. 2010) although Brown Trout populations have shown declines in both growth rates and overall biomass after* P. phoxinus *invasion (Borgstrøm et al. 2010).*

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
	6

- Phoxinus phoxinus *is listed as having a high reproductive potential (USFWS 2014b).*
- *This species has been found in high population densities post-invasion in freshwater lakes (Museth et al. 2007).*

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
	1

- Phoxinus phoxinus *generally are found in shallow, littoral waters with stony substratum, and reproduce sexually in these same areas (Frost 1943).*
- Phoxinus phoxinus *displays high variability in rates of reproductive maturity, clutch size, and frequency of spawning (Mills 1988).*
- *There are no documented adaptations that would be beneficial to establishment*.

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- Phoxinus phoxinus *can be found in a wide variety of conditions throughout most of Europe (Hesthagen and Sandlund 2010, USEPA 2008).*
- *A climate match (USFWS 2014b) showed a high climate match for the Great Lakes region.*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6

Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	7

- *High amounts of ecological and phenotypic plasticity have been demonstrated in the minnows (Museth et al. 2007), and they have a wide range of habitats throughout Europe (USEPA 2008).*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0
Unknown	U
	7

- Phoxinus phoxinus *is found in littoral zones with rocky substrate, with high overlap of habitat with brown trout (Borgstrøm et al. 2010, Museth et al. 2002, Museth et al. 2007, Museth et al. 2010, Naestad and Brittain 2010).*
- Phoxinus phoxinus *is also found in a wide range of cold and well oxygenated habitats from small, fast-flowing streams to large Nordic lowland rivers and from small upland lakes to large oligotrophic lakes (Froese and Pauly 2015).*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0
Unknown	U
	9

- Phoxinus phoxinus *has a high degree of phenotypic plasticity that allows for adaptation to and wide distribution within diverse ecosystem properties (Museth et al. 2007, USEPA 2008).*

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
	9

- *The diet of* P. phoxinus *has considerable variation among chironimids, amphipods, EPT taxa, cladocerans, terrestrial invertebrates, etc. (Oscoz et al. 2006) and has been shown to shift in preference among these with competitive pressure from brown trout (Museth et al. 2010).*
- Phoxinus phoxinus *feeds on algae, plant debris (in rivers), mollusks, crustaceans and insects (Billard 1997).*

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Great Lakes and is not likely to be introduced	-80% total points (at end)
Unknown	U
	9

- *There is no evidence of another species needed for any stage of the* P. phoxinus *life cycle.*

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in	9

the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes)	6
Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0
Unknown	U
	0

- *There is no evidence of any such species needed to faclilitate the establishment and spread of* P. phoxinus.

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0
Unknown	U
	-5%

- *Eurasian Minnows are often prey for salmonids (Borgstrøm et al. 2010, Museth et al. 2003), yet low abundances of these species within the Great Lakes makes predatory prevention unlikely.*

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9
Frequent, moderate inocula	6
Frequent, small inocula OR infrequent, large inocula	3

Infrequent, small or moderate inocula	0
Unknown	U
	U

- *Since the foremost potential vector is ballast water, frequent inoculations could be expected, yet management of ballast water practices should reduce the frequency.*

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
	3

- *Invasive populations have established and spread throughout Norway (Museth et al. 2007).*

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
	6

- *The spread of* P. phoxinus *in Norway has been relatively quick, although its use as a bait species by anglers has been the major vector of spread (Museth et al. 2007).*

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are	-90% total points (at

highly effective in preventing the establishment and spread of this species)	end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent the establishment and/or spread of this species	0
Unknown	U
	0

Establishment Potential Scorecard				
Points	**Probability for Establishment**	A. Total Points (pre-adjustment)		96
>100	High	**Adjustments**		
		B. Critical species	A*(1- 0%)	96
51-99	Moderate	C. Natural enemy	B*(1- 0%)	91.2
		Control measures	C*(1- 0%)	91.2
0-50	Low	**Potential for Establishment**		Moderate
# of questions answered as "unable to determine"	**Confidence Level**			
0-1	High	Total # of questions unknown		1
2-5	Moderate			
6-9	Low	Confidence Level		High
>9	Very low			

Section C: Potential for Impact

<u>IMPACT POTENTIAL RESULTS</u>

Environmental: Moderate

Socio-Economic: Low

Beneficial: Low

***Phoxinus phoxinus* has the potential for moderate environmental impact if introduced to the Great Lakes.**

Following the introduction of *Phoxinus phoxinus*, the composition of the littoral benthos changed from one that was once dominated by Ephemeroptera, Trichoptera, Plecoptera, and *Gammarus lacustris* to one that is dominated by chironomids and ogliochaetes (Naestad and Brittain 2010). By changing the composition of the lower food web, *P. phoxinus* has the potential to alter predator-prey relationships. In subalpine lakes in southern Norway, *P. phoxinus* has been implicated as a carrier of parasites that infect snails, mussels, and some insects (Hesthagen and Sandlund 2010). There are no reports that show that *Phoxinus phoxinus* has outcompeted native species or genetically impacted native species. It has not been indicated that *P. phoxinus* negatively affects water quality or the physical components of an ecosystem.

***Phoxinus phoxinus* has the potential for low socio-economic impact if introduced to the Great Lakes.**

It has been suggested that the presence of *Phoxinus phoxinus* in Lake Øvre Heimdalsvatn has resulted in reduced recruitment and reduced annual individual growth rates in brown trout, a recreationally valuable fish that is stocked (Borgstrøm et al. 2010, Museth et al. 2007). *Phoxinus phoxinus* does not pose a threat to human health or water quality. This species is not known to damage infrastructure. It does not affect any markets or economic sectors, and does not diminish the perceived natural value of the areas it inhabits.

***Phoxinus phoxinus* has the potential for low beneficial impact if introduced to the Great Lakes.**

Anglers in Europe value *P. phoxinus* as bait fish (Museth et al. 2007). There are no reports suggesting that *P. phoxinus* can act as a biological control agent. It is not recreationally or medically valuable. This species is not known to improve water quality or to have a positive ecological impact.

POTENTIAL ENVIRONMENTAL IMPACT

NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1 √
Not significantly	0
Unknown	U

- Phoxinus phoxinus *has been documented transporting parasites which infect snails, mussels, etc. (Hesthagen and Sandlund 2010).*

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered	6

species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1
Not significantly	0 √
Unknown	U

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in the food web)	6
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	1 √
Not significantly	0
Unknown	U

- *Benthic macroinvertebrate populations of* Gammarus lacustris *and* Lepidurus arcticus *declined significantly in a Norwegian lake following introduction of* P. phoxinus *(Museth et al. 2010, Naestad and Brittain 2010).*

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0
Unknown	U √

- *There is no documentation of genetic effects on other populations.*

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1
Not significantly	0
Unknown	U √

- *There is no documentation of negative effects on water quality caused by the minnows.*

E6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1
Not significantly	0 √
Unknown	U

- *Eurasian Minnows do not alter the physical environment*.

Environmental Impact Total	**2**
Total Unknowns (U)	**2**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	**<u>Moderate</u>**
0	0-1	Low
1	0	
0	≥2	Unknown
1	≥1	

<u>POTENTIAL SOCIO-ECONOMIC IMPACT</u>

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1

Not significantly	0 √
Unknown	U

- *There are no documentation of human health impacts.*

S2) Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1
Not significantly	0 √
Unknown	U

- *There are no documentation of damage to infrastructure.*

S3) Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0 √
Unknown	U

- *There are no documentation of negative effects on water quality.*

S4) Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

- *There are no documentation of negative effects on markets or economic sectors.*

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6
Yes, but negative consequences have been small	1 √
Not significantly	0
Unknown	U

- Phoxinus phoxinus *has been implicated in Brown Trout declines (Borgstrøm et al. 2010, Museth et al. 2007). Brown Trout populations have shown declines in systems invaded by Eurasian Minnows (Borgstrøm et al. 2010). Although not a native species in the Great Lakes, Brown Trout is currently stocked by several Great Lakes states as a recreational sport fish (USFWS and GLFC 2010), and adverse effects on this population should be considered.*

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

Socio-Economic Impact Total	**1**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**<u>Low</u>**
1	0	
0	≥2	Unknown
1	≥1	

<u>POTENTIAL BENEFICIAL EFFECT</u>

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular effect. An "Unknown" response is appropriate if the potential for a particular effect might be inferred but has not been explicitly reported or if there is an unresolved debate about a particular effect.

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1
Not significantly	0 √
Unknown	U

B2) Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?

Yes, it is economically important to at least one of these industries	6
Yes, but its economic contribution is small	1 √
Not significantly	0
Unknown	U

- *The European Minnow is frequently used for bait in Europe (USFWS 2012).*

B3) Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local communities and/or tourism	6
It is sometimes employed recreationally, but adds little value to local communities or tourism	1
Not significantly	0 √
Unknown	U

B4) Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR It is potentially important to medicine or research and is currently being or scheduled to be studied	1
Not significantly	0 √
Unknown	U

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1
Not significantly	0 √
Unknown	U

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1
Not significantly	0 √
Unknown	U

Beneficial Effect Total	**1**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**<u>Low</u>**
1	0	
0	≥2	Unknown
1	≥1	

Scientific Name: *Pseudorasbora parva*

Common Name: Stone Moroko, Topmouth Gudgeon, False Rasbora

Synonyms: *Leuciscus parvus* Schlegel, 1842; *L. pusillus* Temmnick et Schlegel, 1846; *Fundulus virescens* Temmnick et Schlegel, 1846; *Leuciscus pusillus* Temmnick et Schlegel, 1846; *Micraspius mianowski* Dybowski, 1869; *Aphiocypris chinensis* Fowler, 1924; *Pseudorasbora altipinna* Nichols, 1925; *Pseudorasbora fowleri* Nichols, 1925; *Pseudorasbora depressirostris* Nichols, 1925; *Pseudorasbora monstruosa* Nichols, 1925; *Pseudorasbora parva parvula* Nichols

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: Unlikely

Hitchhiking/fouling: Low

Unauthorized intentional release: Unknown

Stocking/planting/escape from recreational culture: Unlikely

Escape from commercial culture: Unlikely

Transoceanic shipping: Unlikely

***Pseudorasbora parva* has a low probability of introduction to the Great Lakes (Confidence level: Moderate).**

Potential pathway(s) of introduction: Hitchhiking/Fouling, Unauthorized Intentional Release

This species has been introduced into Europe as a contaminant of imported fish, particularly Golden Orfe and the Common Carp. Whether these species are imported into the Great Lakes region will dictate the likelihood of introduction.

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100
No, this species does not occur near waters connected to the Great Lakes basin and/or is not mobile or able to be transported by wind or water.	0 √
Unknown	U

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100 √
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0
Unknown	U

- Pseudorasbora parva *was introduced in Europe with stockings of herbivorous fishes (*Cyprinus carpio*,* Ctenopharyngodon idella*,* Aristichthys nobilis*,* Hypophathalmichthys molitrix*) imported from China (Panov 2006, Gozlan et al. 2010a).*
- *The introduction and spread of Topmouth Gudgeon in the United Kingdom has been linked to imports and movements of the ornamental variety (Golden Orfe) of Ide,* Leuciscus idus *(Copp et al. 2010). Golden Orfe is sold in the Great Lakes area (e.g., William Tricker, Inc: http://www.tricker.com/Category/golden-orfe-fish).*
- *After Golden Orfe, other species associated with* P. parva *in the United Kingdom include European Catfish* (Silurus glanis)*, North American Landlocked Salmon* (Salmo salar)*, Silver Bream* (Abramis bjoerkna)*, Grass Carp* (Ctenopharyngodon idella)*, andKkoi Carp* (Cyprinus carpio haematopterus) *(Copp et al. 2010, Kohlmann et al. 2003).*

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1 √
Unknown	U

- Pseudorasbora parva *is not present in North America.*

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a) Is this species sold at aquarium/pet/garden stores ("brick & mortar" or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100
No, this species this species is rarely/never sold.	0
Unknown	U √

- *In Europe, has spread via private stocking/introductions, because it is often kept in ponds and sold as ornamental fish or bait fish (S. Nehring, pers. comm. in Gozlan et al. 2010a, Witkowski 2011).*
- *Other secondary pathways, such as cultural or religious acts, have also been responsible for some secondary spread (C. Zhang, pers. comm. in Gozlan et al. 2010a.). For example, people in Tibet traditionally buy small live fish in local fish markets and return them to the wild; in the last decade,* P. parva *has been reported from fish markets in big cities of Tibet such as Lhasa and Xigaze (C. Zhang, pers. comm.in Gozlan et al. 2010a).*

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1
Unknown	U √

- Pseudorasbora parva *is not known to sold in North America, but it may contaminate other fish stocks.*

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0 √
Unknown	U

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is likely to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces), this activity may	Score x 0.25

occur within 20 km of the basin because of the species' popularity/value.	
Unknown	U

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100
No, this species is not commercially cultured in or transported through the Great Lakes region.	0 √
Unknown	U

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40
No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0 √
Unknown	U

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5
Yes, but this species has neither been observed in ballast/fouling ships entering the Great Lakes nor in ports in direct trade with the Great Lakes.	Score x 0.1
No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0
Unknown	U

Vector Potential Scorecard					
Vector		**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind		**0**	x	**0**	Unlikely
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.		**100**	x 0.1	**10**	Low
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)		**U**	x U	**U**	Unknown
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)		**0**	x	**0**	Unlikely
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)		**0**	x	**0**	Unlikely
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling		**0**	x	**0**	Unlikely
Total Unknowns (U)	**2**	**Confidence Level**		Moderate	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely

# of Unknowns (overall)	Confidence Level
0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

ESTABLISHMENT POTENTIAL RESULTS

Status: **Not established in North America, including the Great Lakes**

***Pseudorasbora parva* has a moderate probability of establishment if introduced to the Great Lakes (Confidence level: High).**

The life history traints of this species that would suggest its establishment success include a wide tolerance of environmental conditions, reaching sexual maturity in the first year of life, batch spawning, and nest guarding (Pinder et al. 2005).

The combination of these life history traits, and the range of invaded countries with contrasting climates (i.e. Algeria, Iran, Poland, Tibet) reveal the considerable plasticity and adaptability of *P. parva* to lentic and lotic conditions, Mediterranean, continental and Northern climates, and new food resources and spawning substrata (Gozlan et al. 2010a).

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
	7

- *This species has a wide tolerance of environmental conditions (Pinder et al. 2005).*
- *The combination of its life history traits, and the range of invaded countries with contrasting climates (i.e. Algeria, Iran, Poland, Tibet) reveal the considerable plasticity and adaptability of P. parva (Gozlan et al. 2010a).*
- *This species is limited to freshwater habitats.*

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9
Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
	8

- *This species is found in Scandinavia (Denmark) (Olesen et al. 2003), so is likely to also overwinter in the Great Lakes.*
- *In Czech Republic and Slovakia this specieshas been found to overwinter in lakes that freeze over for 3 months (Rosecchi et al. 1993).*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
	8

- *Although there is limited information about the feeding of the introduced populations, isopods, plecoptera and trichoptera larvae as well as sponges and detritus were found among the stomach contents and it was concluded that* P. parva *is omnivorous hence eats any food at its disposal (Yalçın-Özdilek et al. 2013).*
- *The items most frequently ingested by* P. parva *were benthic crustaceans, insect larvae and zooplankton (Cladocera and Cyclopoid Copepoda). The main benthic crustaceans were Gammaridae, Asellidae, Conchostraca and harpacticoid Copepoda. Among the insects were larvae of Chironomidae, Chaoboridae, Ephemeroptera, Trichoptera and Coleoptera (Rosecchi et al. 1993).*
- P. parva*, particularly juveniles, feeds on phytoplankton (Hliwa et al. 2002); Bacillariophyta and Cyanobacteria were also identified in high proportions in the foregut contents of* P. parva *particularly during summer (Yalçın-Özdilek et al. 2013).*
- P. parva *mainly feeds on zooplankton such as Cladocera, Copepoda, and Rotifera (Yalçın-Özdilek et al. 2013).*
- *In water bodies in China and Germany,* P. parva *was reported to feed on eggs and larvae of native fish species (Stein and Herl 1986, Yang 1996, Xie et al. 2000).*
- P. parva *has also been reported to be a carnivore (Billard 1997).*

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9

Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	0
Unknown	U
	7

- *Introduction of the invasive Asian Cyprinid fish* Pseudorasbora parva *into a 0.3 ha pond in England with a fish assemblage that included* Cyprinus carpio, Rutilus rutilus *and* Scardinius erythrophthalmus *resulted in their establishment of a numerically dominant population in only 2 years; density estimates exceeded 60 ind./m^2 and they comprised >99% of fish present (Britton et al. 2010).*
- *The effect of* P. parva *competition on Common Carp was tested, and found to have no greater effect than intraspecific competition: Additive treatments revealed that the growth of* C. carpio *was significantly suppressed following the introduction of* P. parva *with the magnitude of growth suppression directly proportional to* P. parva *density and biomass. A substitutive treatment that tested for the effect of intraspecific competition revealed that when* C. carpio *was introduced at a similar biomass to* P. parva*, there was no significant difference in the extent of the suppressed growth. At the same density, however, the effect of* C. carpio *(higher biomass) on growth was significantly above that of* P. parva *(lower biomass). This was independent of the initial body sizes of the introduced fishes. Thus, the interspecific competition imposed by* P. parva *was only as strong as the intraspecific competition of* C. carpio *when present at a similar biomass. Notwithstanding, the introduction of such small-bodied fishes remains of great concern because of their increased ability to rapidly establish and form pest populations of high biomass when compared with larger-bodied fishes (Britton et al. 2011).*

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
	2

- *Absolute fecundity has ranged from 121-7124 eggs (Záhorská and Kováč 2009) , with a mean of 963-1054 eggs per season (Yunzhi 2009). Spawning is multi-litter, wish several dozen eggs in a batch (Panov 2006).*
- *Other minnow species in the family Cyprinidae, subfamily Leuciscinae, include: Fathead Minnow (*Pimephales promelas*), 6803-10164 eggs per season, also a batch spawner (Gale and Buynak 1982); Bluntnose Minnow (*Pimephales notatus*), 1112-4195 eggs per season, also a batch spawner (Gale 1983); red shiner (*Notropis lutrensis*), 4701-8248 eggs per season, also a batch spawner (Gale 1986); Emerald Shiner (*Notropis atherinoides*), mean 3410 eggs per season (Campbell and MacCrimmon 1970).*

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
	7

- *This species is a nest guarder (Pinder et al. 2005).*
- P. parva *Sexually matures within the first year of life (Gozlan et al. 2002).*
- *This species exhibits high phenotypic plasticity, i.e., in response to habitat disturbance, increases the number of oocytes and decreases their size (2009).*

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	7

- P. parva *inhabits regions with a wide range of climatic conditions, these include areas similar to the Great Lakes. For example, Slovakia has warm summers and cold, cloudy and humid winters. There are almost no extremes below minimal −20 °C (−4 °F) or above maximal 37 °C (99 °F).*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6

Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	7

- *The wide distribution of* P. parva*, including lakes, rivers and artificial canals, indicates it encounters abiotic conditions similar to those of the Great Lakes.*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0
Unknown	U
	9

- *A study done by Kapusta et al. (2008) found that* P. parva *preferred habitats that were abundantly overgrown with submerged vegetation and avoided areas devoid of macrophytes. Thus, as the bottom cover increased, so did the relative number of this fish.*
- *Spawning occurs at temperatures of 15-19°C (Panov 2006).*
- *The spawning is multi-litter and takes place in the littoral zone. The eggs are laid on plants, sand, stones, mollusc shells, artificial materials such as plastic pipes and other substrata (Gozlan et al. 2010a , Panov 2006).*
- P. parva *inhabits ponds, lakes, rivers, agricultural channels. The species adapts to artificial ditches easily and successfully (Onikura and Nakajima 2013).*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0
Unknown	U
	4

- *As this species can inhabit a wide range of conditions, climate change would likely not be a significant event for this species.*

- *It may do better than native species as it exhibits high phenotypic plasticity in response to habitat disturbance (Záhorská and Kováč 2013).*
- *The impacts of increased salinization are unknown.*

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
	9

- *Although there is limited information about the feeding of the introduced populations, isopods, plecoptera and trichoptera larvae as well as sponges and detritus were found among the stomach contents and it was concluded that* P. parva *is omnivorous hence eats any food at its disposal (Yalçın-Özdilek et al. 2013).*

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Great Lakes and is not likely to be introduced	-80% total points (at end)
Unknown	U
	9

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes)	6
Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0
Unknown	U
	0

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0
Unknown	U
	-10%

- *Predators include Pike (*Esox lucius*), Pike-perch (*Sander lucioperca*), Perch (*Perca fluviatilis*), and potentially other piscivores, but these predators have not prevented P. parva from establishing throughout Europe (Britton et al. 2010, Panov 2006).*
- *The biotic resistance against introduced Topmouth Gudgeon* (Pseudorasbora parva) *(a highly invasive fish in Europe) by Resident Carp* Cyprinus carpio *was tested in experimental mesocosms. The introduction scenario was six adult* P. parva *(three male, three female) on a single occasion. Resistance to their establishment was provided by three and six resident* C. carpio *whose effects on* P. parva *growth and reproduction were compared to a Control (no resident fish at the time of introduction) and treatments containing three and six* P. parva. *After 120 days, the growth rates of the introduced* P. parva *were significantly depressed in C. carpio presence and in mesocosms with three* C. carpio *present, significantly decreased numbers of 0+*P. parva *were recorded. Where*

six C. carpio *were present, no 0+*P. parva *were recorded, indicating resistance strength increased with carp abundance. However, the authors acknowledge the small mesocosms allowed no opportunity for resource segregation, and as such this effect may not occur so strong in the wild (Britton 2012).*

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9
Frequent, moderate inocula	6
Frequent, small inocula OR infrequent, large inocula	3
Infrequent, small or moderate inocula	0
Unknown	U
	U

- *This will depend on importation of stock at risk of contamination.*

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
	9

- *This species is native to east Asia, in Europe it was first recorded in 1961 from southern Romania and Albania. In 1972 the species was recorded from the European part of the former USSR – the Danube delta and Dniester. In slightly over 40 years it has almost entirely colonized Europe, proceeding rapidly from east to west, invading 32 countries including Hungary, former Czechoslovakia, France, Austria, Germany, Belgium, the Netherlands, Bulgaria, northern Greece, Turkey and the western part of the Balkans, Poland, Italy, England and Denmark (Gozlan et al. 2002, Panov 2006).*

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced	6

ranges)	
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
	9

- *This species was first noted in Poland in 1990. By the end of the 1990s, this fish had spread throughout all the regions of Poland inhabiting lakes, ponds, and rivers (Kotusz and Witkowski 1998).*
- *In slightly over 40 years this species has almost entirely colonized Europe (Panov 2006).*

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing the establishment and spread of this species)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent the establishment and/or spread of this species	0
Unknown	U
	0

Establishment Potential Scorecard				
Points	**Probability for Establishment**	A. Total Points (pre-adjustment)		102
>100	High	**Adjustments**		
		B. Critical species	A*(1- 0%)	102
51-99	Moderate	C. Natural enemy	B*(1- 0%)	91.8
		Control measures	C*(1- 0%)	91.8
0-50	Low	**Potential for Establishment**		Moderate
# of questions answered as "unable to determine"	**Confidence Level**			
0-1	High			1

2-5	Moderate	Total # of questions unknown	
6-9	Low	Confidence Level	High
>9	Very low		

Section C: Potential for Impact

IMPACT POTENTIAL RESULTS

Environmental: High

Socio-Economic: Unknown

Beneficial: Low

***Pseudorasbora parva* has the potential for high environmental impact if introduced to the Great Lakes.**

Pseudorasbora parva has 84 parasite species although generally only a few of these are transferred to a new site of introduction. Specifically, these are typically zoosporic fungi (Czeczuga et al. 2002), parasites such as *Diplostomum spataceum* in Georgia (Kakalova and Shonia 2008), and viruses such as fry rhabdovirus (PFR) in Germany (Ahne and Thomsen 1986). The PFR virus, which causes acute disease of *Esox lucius* fry, has been isolated from *P. parva*. The two most severe parasites found associated with *P. parva* in its invasive range are *Anguillicola crassus* and rosette agent *Sphaerothecum destruans* (Gozlan et al. 2005, Gozlan et al. 2009, Gozlan et al. 2010b, Witkowski 2011). These parasites if carried over after introduction could have destructive impacts on similar native Great Lakes species.

Pseudorasbora parva is one of the most (or the most) dominant species in fish assemblages where it is established (Kapusta et al. 2008, Tang et al. 2013). If introduced into the Great lakes, *P. parva* could cause noticeable stress or decline in at least one native population. Predator-prey relationships would be significantly adversely affected by the introduction *of P. parva*.

Current research on the potential for socio-economic impacts to result from *Pseudorasbora parva* if introduced to the Great Lakes is inadequate to support proper assessment.

It is unknown whether *P. parva* poses hazards or threats to human health. *P. parva* does carry parasites that are able to infect humans (Bao 2012, Pak et al. 2009, Xu et al. 2010, Zhou et al. 2008) but there are no documentations of *P. parva* directly transferring these to humans (Gozlan et al. 2010a). A series of three (successful) eradication exercises from United Kingdom lakes has cost approximately £130,000 in public funds (Britton et al. 2008).

There is little or no evidence to support that *Pseudorasbora parva* has the potential for significant beneficial impacts if introduced to the Great Lakes.

It has not been indicated that *Psuedorasbora parva* can be used for the control of other organisms or improving water quality. There is no evidence to suggest that this species is commercially, recreationally, or medically valuable. It does not pose significant positive ecological impacts. *P. parva* has no economic value and it is only used by sport fishermen as bait fish (Lenhardt et al. 2011).

POTENTIAL ENVIRONMENTAL IMPACT

NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6 √
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1
Not significantly	0
Unknown	U

- P. parva *has 84 parasite species: Protozoa (40), Monogenea (10), Cestoda (3), Trematoda (16), Nematoda (3), Acanhocephala (6), Bivalvia (1), Crustacea (4), Hirudinea (1) (Margaritov and Kiritsis 2011), although generally only a few of these are transferred to a new site of introduction.*
- *Specifically, these are typically zoosporic fungi (Czeczuga et al. 2002), parasites such as* Diplostomum spataceum *in Georgia (Kakalova and Shonia 2008) and viruses such as fry rhabdovirus (PFR) in Germany (Ahne and Thomsen 1986). The PFR virus, which causes acute disease of* Esox lucius *fry, has been isolated from* P. parva*. The two most severe parasites found associated with* P. parva *in its invasive range are* Anguillicola crassus *and rosette agent* Sphaerothecum destruans *(Gozlan et al. 2005, Gozlan et al. 2009, Gozlan et al. 2010b, Witkowski 2011).*
- Sphaerothecum destruans*:*
    - P. parva *carries a pathogen that has caused increased mortality and completely inhibited spawning in an endangered European cyprinid,* Leucaspius delineatus*. Mortality in laboratory experiments was 69%; mortality in a large outdoor pond was 96%. Preliminary examination indicates other cyprinids and salmonids are also susceptible. This threat is caused by an infectious pathogen, a rosette-like intracellular eukaryotic parasite that is a deadly, nonspecific agent. It is probably carried by healthy* P. parva *fish, and could decrease fish biodiversity in Europe, as well as having implications for commercial aquaculture (Gozlan et al. 2005).*
    - *The emerging rosette-like agent is* Sphaerothecum destruens*, originally found to be responsible for disease outbreaks in captive salmon in the United States. Unlike the situation in the United States, its low host specificity and occurrence in invasive fishes presents a risk of spread from wild invasive populations to sympatric populations of susceptible native fish and as such represents a risk for fisheries, as movement of fish for stocking purposes is common practice. Fish transmission may occur when infected fish release the parasite with bile, urine, and seminal and ovarian fluids during spawning. Shedding from the gut epithelium and even the skin and gills may be additional sources (Gozlan et al. 2009).*
- *The prevalence of* Clonorchis sinensis metacercariae *was 100% in* Pseudorasbora parva*. Human beings and other piscivorous mammals become infected with* C. sinensis *when they consume raw or undercooked freshwater fishes and shrimp infected by* C. sinensis metacercaria *(Zhou et al. 2008). The parasite causes clonorchiasis and is often associated with many human diseases such as biliary calculi, cholecystitis, liver cirrhosis, and even cholangiocarcinoma (Bao 2012, Pak et al. 2009, Xu et al. 2010)..*
- *The marked isotopic shifts shown in all taxa in the* P. parva *invaded pond (^{13}C-enriched, ^{15}N depleted) were indicative of a shift to a cyanobacteria-dominated phytoplankton community. This may have resulted from grazing by* P. parva *of zooplankton, which in turn would have consumed unpalatable phytoplankton such as cyano-bacteria (Britton et al. 2010).*

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1 √
Not significantly	0
Unknown	U

- *Where established, this species is one of the most (or the most) dominant species in the fish assemblage. In Poland,* P. parva *was the most dominant fish caught: it comprised 32.6% of all the fish caught, and its permanence of occurrence in the samples was 60% (Kapusta et al. 2008). In China,* P. parva *was the most dominant fish caught comprised 25.432% of all fish caught, its permanence of occurrence in the samples was 87.50% (Tang et al. 2013).*
- *Introduction of the invasive Asian cyprinid fish* Pseudorasbora parva *into a 0.3 ha pond in England with a fish assemblage that included* Cyprinus carpio, Rutilus rutilus *and* Scardinius erythrophthalmus *resulted in their establishment of a numerically dominant population in only 2 years; density estimates exceeded 60 ind./m^2 and they comprised >99% of fish present (Britton et al. 2010).*
- *The effect on Common Carp was tested, and found no greater effect than intraspecific competition: Additive treatments revealed that the growth of* C. carpio *was significantly suppressed following the introduction of* P. parva *with the magnitude of growth suppression directly proportional to* P. parva *density and biomass. A substitutive treatment that tested for the effect of intraspecific competition revealed that when* C. carpio *were introduced at a similar biomass to* P. parva*, there was no significant difference in the extent of the suppressed growth. At the same density, however, the effect of* C. carpio *(higher biomass) on growth was significantly above that of* P. parva *(lower biomass). This was independent of the initial body sizes of the introduced fishes. Thus, the interspecific competition imposed by* P. parva *was only as strong as the intraspecific competition of* C. carpio *when present at a similar biomass. Notwithstanding, the introduction of such small-bodied fishes remains of great concern because of their increased ability to rapidly establish and form pest populations of high biomass when compared with larger-bodied fishes (Britton et al. 2011).*

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in the food web)	6 √
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	1
Not significantly	0
Unknown	U

- P. parva *feeds on juveniles of native fish. In the open waters of southern Europe it has probably contributed to a decrease in abundance or even disappearance of some autochthonous cyprinids (Panov 2006).*
- *Consumes larger species of planktonic crustaceans, which results in an increase in the quantity of phytoplankton, increasing eutrophication of the water bodies (Adamek and Sukop 2000).*
- *Comparison with stable isotope analysis values collected from an adjacent pond free of* P. parva *revealed a simplified food web in* P. parva *presence, but with an apparent trophic position shift for several fishes, including* S. erythrophthalmus *which appeared to assimilate energy at a higher trophic level, probably through* P. parva *consumption (Britton et al. 2010).*

- *In laboratory experiments at densities similar to that in the environment,* P. parva *larvae depressed the populations of most planktonic cladoceran and rotifer species but not the abundances of copepod nauplii or the periphytic rotifers* Monostyla *spp. and* Lecane *spp. Gut content analyses showed that the fish larvae strongly selected for the periphytic rotifer* Lecane *spp. (Nagata et al. 2005).*

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6 √
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0
Unknown	U

- Pseudorasbora pumila*, an indigenous species in Japan and ranked as an endangered species in the Japanese Red Data Book, has largely been replaced by the accidental introduction of the gudgeon because of intensive hybridization (Konishi and Takata 2004, Konishi et al. 2003).*

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1
Not significantly	0 √
Unknown	U

E6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1
Not significantly	0 √
Unknown	U

Environmental Impact Total	**19**
Total Unknowns (U)	**0**

Scoring		
Score	# U	**Impact**
>5	Any	**High**
2-5	Any	Moderate
0	0-1	Low
1	0	
0	≥2	Unknown
1	≥1	

POTENTIAL SOCIO-ECONOMIC IMPACT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1
Not significantly	0
Unknown	U √

- *The prevalences of* Clonorchis sinensis metacercariae *was 100% in* Pseudorasbora parva*. Human beings and other piscivorous mammals become infected with* C. sinensis *when they consume raw or undercooked freshwater fishes and shrimp infected by* C. sinensis metacercaria *(Zhou et al. 2008). The parasite causes clonorchiasis and is often associated with many human diseases such as biliary calculi, cholecystitis, liver cirrhosis, and even cholangiocarcinoma (Bao 2012, Pak et al. 2009, Xu et al. 2010).. However, this fish is rarely intentionally consumed raw, and these species have not been reported in introduced range (Fan 1998).*
- *Other food-borne trematodes, for which* P. parva *acts as an intermediate host and so may result in transmission to humans, include* Opisthorchis viverrini *(Sithithaworn and Haswell-Elkins 2003) and* Clinostonum complanatum *(Aohagi et al. 1992)* O. viverrini *poses the highest risk to human health causing opisthorchiasis by parasitizing the liver and biliary passages of their hosts, and there are approximately 9 million people infected globally. These species have not been reported in introduced range (Gozlan et al. 2010a).*

S2) Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1
Not significantly	0 √
Unknown	U

S3) Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0 √
Unknown	U

S4) Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1 √
Not significantly	0
Unknown	U

- *The prevalence of* Pseudocapillaria tomentosa *in Topmouth Gudgeon was 45.1%.* Pseudocapillaria tomentosa *infection was associated with mortality in captive Tiger Barbs,* Puntius tetrazona*, and other ornamental fish (Moravec et al. 1984). Heavy infections of* P. tomentosa *in pond-reared carp or other fish species of economic importance can cause economic problems with fish production (Mihok et al. 2011).*
- *In the native range,* P. parva *is the second intermediate host for cosmopolitan ligulid tapeworms and to species of the* Digramma *genus that have been the cause of high mortalities in freshwater commercial fisheries in China and Russia. These species have not been reported in introduced range (Gozlan et al. 2010b).*
- *A series of three (successful) eradication exercises from United Kingdom lakes that has cost approximately £130,000 of public funds (Britton et al. 2008).*

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

Socio-Economic Impact Total	**1**
Total Unknowns (U)	**1**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	Low
1	0	
0	≥2	**Unknown**
1	≥1	

POTENTIAL BENEFICIAL EFFECT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular effect. An "Unknown" response is appropriate if the potential for a particular effect might be inferred but has not been explicitly reported or if there is an unresolved debate about a particular effect.

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1
Not significantly	0 √
Unknown	U

B2) Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?

Yes, it is economically important to at least one of these industries	6
Yes, but its economic contribution is small	1
Not significantly	0 √
Unknown	U

- *This species has no economic value and it is only used by sport fishermen as bait fish (Lenhardt et al. 2011).*

B3) Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local	6

communities and/or tourism	
It is sometimes employed recreationally, but adds little value to local communities or tourism	1
Not significantly	0 √
Unknown	U

B4) Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR It is potentially important to medicine or research and is currently being or scheduled to be studied	1
Not significantly	0 √
Unknown	U

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1
Not significantly	0 √
Unknown	U

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1
Not significantly	0 √
Unknown	U

- *The marked improvement in growth of a piscivore (*Scardinius erythrophthalmus*) following the invasion of* P. parva *in England indicates that feeding conditions certainly improved for this species (Britton et al. 2010).*

Beneficial Effect Total	**0**
Total Unknowns (U)	**0**

<table>
<tr><th colspan="3">Scoring</th></tr>
<tr><th>Score</th><th># U</th><th>Impact</th></tr>
<tr><td>>5</td><td>Any</td><td>High</td></tr>
<tr><td>2-5</td><td>Any</td><td>Moderate</td></tr>
<tr><td>0</td><td>0-1</td><td rowspan="2"><u>Low</u></td></tr>
<tr><td>1</td><td>0</td></tr>
<tr><td>0</td><td>≥2</td><td rowspan="2">Unknown</td></tr>
<tr><td>1</td><td>≥1</td></tr>
</table>

Scientific Name: *Rutilus rutilus*
Linnaeus, 1758

Common Name: Roach

Synonyms: *Cyprinus rutlius*, *Cyprinus ruttilus*, *Gardonus rutilus*, *Leuciscus rutilus*

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: Unlikely

Hitchhiking/fouling: Unlikely

Unauthorized intentional release: Low

Stocking/planting/escape from recreational culture: Unlikely

Escape from commercial culture: Unlikely

Transoceanic shipping: Moderate

***Rutilus rutilus* has a moderate probability of introduction to the Great Lakes (Confidence level: High).**

Potential pathway(s) of introduction: Unauthorized Intentional Release, Transoceanic Shipping (ballast water)

Rutilus rutilus is sold as baitfish and is used for recreational fishing in Europe (Froese and Pauly 2015, Griffiths 1997); however, this species is not easily obtained in the Great Lakes region. This species may be taken up in ballast but its survival may be substantially impacted by current ballast regulatory requirements. *Rutilus rutilus* occurs in ports that have direct trade connections with the Great Lakes (Härmä et al. 2008, Lappalainen et al. 2001, NBIC 2009).

Rutilus rutilus does not currently occur near waters connected to the Great Lakes basin. It is not known to hitchhike or foul recreational gear. This species is not cultured, stocked, or sold in the Great Lakes region.

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100

No, this species does not occur near waters connected to the Great Lakes basin and/or is not mobile or able to be transported by wind or water.	0 √
Unknown	U

- *There are no known introductions of* Rutilus rutilus *in the United (USFWS 2012).*
- *The species is found in the United Kingdom and Northern Europe (Froese and Pauly 2015).*

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0 √
Unknown	U

- *There is no reported transport of* R. rutilus *in North America (USFWS 2012).*

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a) Is this species sold at aquarium/pet/garden stores ("brick & mortar" or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100 √

No, this species this species is rarely/never sold.	0
Unknown	U

- Rutilus rutilus *is used very little for commercial fishing, but it is used as bait and for recreational fishing (Froese and Pauly 2015).*
- Rutilus rutilus *was introduced to Italy and other countries unintentionally by anglers using it as live bait (Griffiths 1997).*

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1 √
Unknown	U

- *Roach is not found in the Great Lakes nor can it be obtained live in North America.*

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0 √
Unknown	U

- *Roach is not found in the Great Lakes nor can it be obtained live in North America.*
- *Roach has a low commercial value and is used just for recreational fishing (Froese and Pauly 2015).*

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is likely to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces), this activity may occur within 20 km of the basin because of the species' popularity/value.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100
No, this species is not commercially cultured in or transported through the Great Lakes region.	0 √
Unknown	U

- *Ireland is the closest region where Roach have been reported (Ferguson 2008).*
- *It has low commercial value and is used just for recreational fishing (Froese and Pauly 2015).*

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80 √
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40
No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0
Unknown	U

- Rutilus rutilus *has not been reported to be found in ballast water, but it has high survival in a variety of environments (USFWS 2012).*

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5 √
Yes, but this species has neither been observed in ballast/fouling ships entering the Great Lakes nor in ports in direct trade with the Great Lakes.	Score x 0.1
No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0
Unknown	U

- *The species is prevalent in the Baltic and Black seas near coastal area (Härmä et al. 2008).*
- *In the Northern Baltic Sea, Roach was abundant in gill net catches (Lappalainen et al. 2001).*

Vector Potential Scorecard				
Vector	**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind	**0**	x	**0**	Unlikely
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.	**0**	x	**0**	Unlikely
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)	**0**	x	**10**	Low
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)	**0**	x	**0**	Unlikely
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)	**0**	x	**0**	Unlikely
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling	**80**	x 1.0	**80**	Moderate
Total Unknowns (U)	**0**	**Confidence Level**	High	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low

0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

ESTABLISHMENT POTENTIAL RESULTS

Status: **Not established in North America, including the Great Lakes.**

***Rutilus rutilus* has a moderate probability of establishment if introduced to the Great Lakes (Confidence level: Moderate).**

The climate of the introduced and native range of *R. rutilus* is moderately similar to the climate of the Great Lakes (USFWS 2012). *Rutilus rutilus* primarily occurs in brackish and estuarine waters, but it has become abundant in the freshwater Lower Lough Erne (Griffiths 1997). *Rutilus rutilus* occurs in waters that have ice cover over the winter (Geraudie et al. 2010, Härmä et al. 2008), so it is likely that it can overwinter in the Great Lakes. Predictions on how climate change affects *R. rutilus* are contradictory (Härmä et al. 2008). Shorter duration of ice cover and warmer temperatures may benefit reproductive success; however, salinity negatively impacts embryonic development, so salinization may reduce its ability to establish in the Great Lakes.

This species has a broad, flexible omnivorous diet (Horppila et al. 2000, Volta and Jepsen 2008) and will likely find a suitable food source in the Great Lakes. It has the potential to compete with native species, but there are no predictions regarding species in the Great Lakes. After the introduction of *R. rutilus* to Northern Ireland, there was a decline in Tufted Duck (*Aythya fuligula*) populations, and it was suggested that it was caused by competition for zoobenthos (Winfield et al. 1992). Zebra mussels are preyed on by *R. rutilus* (Lappalainen et al. 2005) and may potentially facilitate its establishment as an abundant food source in the Great Lakes.

Rutilus rutilus has a slightly higher fecundity compared to fish in the same taxon. *Rutilus rutilus* has a relative fecundity of 87 eggs/g (Jamet and Desmolles 1994) while *R. frisii kutum* has a relative fecundity of 57 eggs/g (Yousefian and Mosavi 2008). Freshwater habitats and eutrophication of the Great Lakes may enhance *R. rutilus* reproduction and development (Härmä et al. 2008, Sandström and Karås 2002).

The survey that led to the first report of *R. rutilus* in Lake Maggiore, Italy, had evidence that it had become one of the most abundant fish in the lake (Volta and Jepsen 2008). In Lake Maggiore, *R. rutilus* had a higher growth rate than in other European waters. In Ireland, the spread of *R. rutilus* was relatively slower; after introduction in 1889, it took several decades for it to become abundant (Griffiths 1997).

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
	7

- *Adult Roaches like to live in brackish waters with salinities of 10% to 15%, while reproduction occurs in ranges of <3.5% (.35 ppt) (Bănărescu and Coad 1991, Härmä et al. 2008). Upper salinity ranges for reproduction have been experimentally determined to be between 7.5% to 10% (Härmä et al. 2008).*
- *However, other reports of this species state that it lives in both fresh and brackish water, and breeds among dense submerged vegetation in backwaters or lakes, flooded meadows or in shallow, fast-flowing river habitats on plant or gravel bottom (Froese and Pauly 2015).*
- Rutilus rutilus *is found in a varieties of waters such as the Baltic, Caspian, and Aral Sea with a temperature tolerance of <12-28°C and an optimum growth temperature of 20-27°C (Linlokken et al. 2010). Lower temperature ranges have not been researched experimentally.*
- *Feeding and growth of* R. rutilus *is reduced at temperatures <12°C (Linlokken et al. 2010).*
- *Early life stages of* R. rutilus *are sensitive to salinity* (*Härmä et al. 2008).*
- *It occurs in waters that have temperatures of 4°C (Geraudie et al. 2010) and have been shown to tolerate temperatures up to 30°C (Cocking 1958). At high temperatures of 30°C, it cannot tolerate oxygen levels under 1 mg/L.*

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9
Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
	6

- *Studies were not done in lower temperatures to see the survival of* R. rutilus*, but it is hypothesized that the swimming speed and metabolism would be lowered and the feeding habits would be affected (Linlokken et al. 2010).*
- *This species occurs in waters in France, which experience water temperatures of 4-6°C in the winter (Geraudie et al. 2010).*
- *This species occurs in the Baltic Sea,and spawn shortly after ice breakup (Härmä et al. 2008).*
- *The optimum factors for reproduction are temperatures between 4° to 19.5 °C and salinity ranges from 0% to 3.5%, allowing it to reproduce up to 100,000 pale yellow eggs that are adhesive to submersed aquatic vegetation (Härmä et al. 2008).*
- *Other temperatures beneficial to* R. rutilus*' survival are 8° to 28°C because they are known to thrive in those waters (Nõges and Jarvet 2005).*

- Rutilus rutilus *is found in a varieties of waters such as the Baltic, Caspian, Black Sea and Aral Sea with a temperature tolerance of <12°C - 28°C and an optimum growth temperature of 20-27°C (Linlokken et al. 2010).*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
	6

- Rutilus rutilus *prefers a diet consisting of primary producers and small plankton but can also widen its spectrum to things such as detritus in the presence of other competitors such as perch (Horppila 2000). It also likes to feed on algae, crustaceans, water plants and insect larvae based on the life stage it is in (Ferguson 2008).*
- Rutilus rutilus *has the ability to shift its diet from the littoral to the pelagic zones in order to avoid high predation and competition (Froese and Pauly 2015). Research in Finland showed that juvenile roach feed on zooplankton and switch their diet to plant material during their adult stage (Horppila 2000).*

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	0
Unknown	U
	7

- Rutilus rutilus *is a dominant competitor and it has been shown to reduce abundance of species such as Atlantic Salmon, Brown Trout, Pollan, and its biggest competitor, Perch (Ferguson 2008).*
- Rutilus rutilus *can comprise up to 70% of the fish biomass due to the feeding habits that can directly and indirectly deplete food resources (Ferguson 2008, Griffiths 1997).*
- *Ireland had the latest invasion of* R. rutilus *and it was found that Zebra mussels act as a control for the Roach population by eating the plankton which is the roach's primary food source (Minchin et al. 2003).*
- *After the introduction of* R. rutilus*, the once common Tufted Duck,* Aythya fuligula *experienced a decline in their population (Winfield et al. 1992).*

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
	6

- Rutilus rutilus *has a high fecundity that can vary with the different regions and habitats. In Ireland it was found to reproduce <100,000 eggs, which can tend to have dramatic variations from year to year (Ferguson 2008).*
- Rutilus rutilus *has a high fecundity compared to fish in the same taxon.* Rutilus rutilus *has a relative fecundity of 87 eggs/g (Jamet 1994) while* R. frisii kutum *has a relative fecundity of 57 eggs/g (Yousefian and Mosavi 2008).*

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
	5

- *Roach has a high rate of reproduction and can spawn from April to June. It produces adhesive eggs that can stick to plants and stones in shallow waters (Ferguson 2008).*
- *Its schooling behavior can be beneficial by protecting its young and keeping the abundance high (Linlokken et al. 2010).*
- *The Great Lakes would provide an optimum habitat for reproduction because* R. rutilus *prefers ranges of 0 to 3.5 ppt during its spawning season, therefore the freshwater of Great Lakes would be ideal (Härmä et al. 2008).*
- *Research has shown that* R. rutilus *spawns at temperature between 8° - 19.4 °C optimally (Nõges and Jarvet 2005).*

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- *The* R. rutilus *native range has been found to be in latitude 68-71°N, but can tolerate ranges of 71°N to 36°N (Froese and Pauly 2015). The Great Lakes latitudes are around 41° - 49° N, which matches the ranges of the Caspian Sea (40° N), where* R. rutilus *can be found in high abundance.*
- R. rutilus *prefers backwaters or deep parts of lakes to live in over the winter (Froese and Pauly 2015).*
- *Climate, of locations where* R. rutilus *is documented, is highly matched with that of the continental United States (USFWS 2012).*
    - Rutilus rutilus *is found in a varieties of waters such as the Baltic, Caspian, Black Sea and Aral Sea. The Great Lakes and Ponto-Caspian region are climatically compatible, which is one of the attributing factors to the success of Ponto-Caspian species in the Great Lakes (Reid and Orlova 2002)*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- *Roach can live in low oxygen environment and nutrient enriched waters (Ferguson 2008). According to the map from the Global Biodiversity Information Facility (GBIF 2010), which shows the distributions of* R. rutilus *throughout the globe, Great Lakes seems to somewhat match the climate and areas where Roach is found (USFWS 2012).*
- *Although with this information Roach might have a small chance to adapt to the Great Lakes, it is most likely not going to because it prefers to spend its adulthood in brackish waters.*
- Rutilus rutilus *lives in both fresh and brackish water and pH range of 10 to 15 (Froese and Pauly 2015).*
- Rutilus rutilus *primarily occurs in brackish and estuarine waters, but it has become abundant in the freshwater Lower Lough Erne (Griffiths 1997).*
- *Abiotic factors and climatic conditions of the native and introduced ranges of this species are quite similar to the Great Lakes, making the region compatible (Grigorovich et al. 2003, Reid and Orlova 2002).*
- *Great Lakes underwent similar anthropogenic eutrophication as the Ponto-Caspian region (Reid and Orlova 2002). Surface water temperature is similar between the Great Lakes and Ponto-Caspian seas (Grigorovich et al. 2003, Reid and Orlova 2002, USEPA 2008).*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0
Unknown	U
	9

- *Although this species prefers mainly lowland areas, it can also be seen abundantly in nutrient-rich lakes and large to medium sized rivers and backwaters (Froese and Pauly 2015). Roach prefer eutrophic lakes because it gives them the benefit to capture more zooplankton because of their ability to switch from submerged vegetation to primary producers in the instance of increased turbidity or decrease in vegetation (Horppila et al. 2000). Adult roach will move to the pelagic zone during growing season in the early summer due to metabolic requirements and feeding habits (Horppilla et al. 2000).*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0
Unknown	U
	6

- *Climate change would be beneficial in many ways for adult roach. Studies shown that with increasing temperatures, shorter winters, and lower salinity,* R. rutilus *is able to spawn sooner for longer periods of time (Nõges and Jarvet 2005).*
- *Predictions on how climate change affects* R. rutilus *are contradictory (Härmä et al. 2008). Shorter duration of ice cover and warmer temperatures may benefit reproductive success; however, salinity negatively impacts embryonic development, so salinization may reduce its ability to establish in the Great Lakes.*

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6

Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
	9

- Rutilus rutilus *initially feeds on plankton and in the case of predators or other environmental changes, it can broaden their feeding range. Being an omnivorous fish, it has the advantage to feed on zooplankton, zoobenthos, detritus, macrophytes, and aquatic vegetation (Horpilla et al. 2000, Winfield 1986).*
- *In eutrophic lakes, in the presence of predators or other competitors such as perch,* R. rutilus *is able to switch to detritus and primary producers (Horppila et al. 2000).*

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Great Lakes and is not likely to be introduced	-80% total points (at end)
Unknown	U
	9

- Rutilus rutilus *does not depend on any other species to survive (Horppila et al. 2000, USFWS).*

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established	6

and spread in the Great Lakes)	
Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0
Unknown	U
	6

- Rutilus rutilus *feeds on Zebra mussels (Lappalainen et al. 2005), which have established in the Great Lakes in high abundance.*

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0
Unknown	U
	-10%

- *Stokes et al. (2006) suggest that the recent invasion of Zebra mussel may reduce plankton and somewhat control* R. rutilus *populations, but there is no current evidence that this is effective at reducing* R. rutilus *populations.*

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9
Frequent, moderate inocula	6
Frequent, small inocula OR infrequent, large inocula	3
Infrequent, small or moderate inocula	0

Unknown	U
	U

- *According to Ferguson (2008),* R. rutilus *was introduced in Ireland illegally by anglers that used the fish as bait.*
- *The United States Fish and Wildlife Services (2012) surveyed that Roach has little commercial use and it mostly used for recreational fishing.*
- *Its propagule pressure via ballast water introduction has not been reported.*

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
	U

- *Roach has been introduced to Spain, northern Italy, Ireland, the lakes region of the United Kingdom, the Azores Islands, Portugal, Kazakhstan, Cyprus, Morocco, Australia, and Madagascar (USFWS 2012).*
- Rutilus rutilus *is established and expanding in almost all introduced locations except for Madagascar (Froese and Pauly 2015).*

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
	5

- *Ferguson (2008) states that* R. rutilus *was introduced in Ireland in 1889 but was not seen in high abundance for a few decades. Roaches are known to rapidly reproduce in high numbers during their spawning season depending on temperatures and salinity levels (Ferguson 2008, Härmä et al. 2008).*
- *The survey that led to the first report of* R. rutilus *in Lake Maggiore, Italy, had evidence that it had become one of the most abundant fish in the lake (Volta and Jepsen 2008).*

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing the establishment and spread of this species)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent the establishment and/or spread of this species	0
Unknown	U
	0

- *No control methods to prevent the establishment or spread of the roach are in place in the Great Lakes.*

Establishment Potential Scorecard				
Points	**Probability for Establishment**	A. Total Points (pre-adjustment)		97
		Adjustments		
>100	High	B. Critical species	A*(1- 0%)	97
51-99	Moderate	C. Natural enemy	B*(1- 10%)	87.3
		Control measures	C*(1- 0%)	87.3
0-50	Low	**Potential for Establishment**		Moderate
# of questions answered as "unable to determine"	**Confidence Level**			
0-1	High	Total # of questions unknown		2
2-5	Moderate			
6-9	Low	Confidence Level		Moderate
>9	Very low			

Section C: Potential for Impact

IMPACT POTENTIAL RESULTS

Environmental: High

Socio-Economic: Moderate

Beneficial: Moderate

Rutilus rutilus **has the potential for high environmental impact if introduced to the Great Lakes.**

Arctic Charr (*Salvelinus alpinus*) has been recently impacted by eutrophication, climate change, and the growing populations of *R. rutilus*. It has been suggested that *R. rutilus* may compete with Arctic Charr in England for zooplankton (Winfield et al. 2008). After its introduction to Lake Erne, the rudd disappeared (Cragg-Hine 1973). After the introduction of *R. rutilus* to Northern Ireland, there was a decline in the Tufted Duck (*Aythya fuligula*) populations, and it has been implicated that it was caused by competition for zoobenthos (Winfield et al. 1992). *Rutilus rutilus* may have altered predatory-prey relationships as a food source for the piscivorous Great Crested Grebes (*Podiceps cristatus*), which experienced a population increase after its introduction. *Rutilus rutilus* may be a carrier of parasites such as tapeworm (*Ligula intestinalis*) (Carter et al. 2005).

Studies conducted by Horppila and Kairesalo (1990) provided evidence that *Rutilus rutilus* has negatively impacted water quality and maintained high algal productivity in southern Finland. Bioturbation occurred when *R. rutilus* was feeding, which released nutrients from the sediments. During times of low zooplankton abundance, *R. rutilus* caused high phosphorous loading and turbidity (Horppila and Kairesalo 1992).

Rutilus rutilus **has the potential for moderate socio-economic impact if introduced to the Great Lakes.**

Rutilus rutilus may curtail efforts to improve water quality; after initial recovery of a lake in southern Finland, algal blooms increased and it was suggested that *R. rutilus* had maintained high algal productivity and biomass (Horppila and Kairesalo 1990). *Rutilus rutilus* may negatively impact commercially fisheries and recreational fishing by affecting Atlantic Salmon and Brown Trout stocks (Stokes et al. 2006). *Rutilus rutilus* does not pose a threat to human health and does not damage infrastructure.

Rutilus rutilus **has the potential for moderate beneficial impact if introduced to the Great Lakes.**

In Europe, *Rutilus rutilus* is not economically valued for commercial fisheries (Härmä et al. 2008). It is valued as a bait fish for recreational fishing (Stokes et al. 2006). It has not been used as biological control. *Rutilus rutilus* is not valued for medicinal or research purposes. It does not remove toxins, increase water quality, or have a positive ecological impact.

POTENTIAL ENVIRONMENTAL IMPACT

NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1 √
Not significantly	0
Unknown	U

- *Parasitic infestations such as worm cataract and blackspot disease have been assessed and tied to Roach (USFWS 2012).*

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6 √
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1
Not significantly	0
Unknown	U

- *Rudd populations have been forced to move to other habitats while having a large decline in abundance because of high competition with* R. rutilus *(Stokes et al. 2006).*
- *Atlantic Salmon and Brown Trout abundances have been negatively impacted as well by Roach (Ferguson 2008).*
- *Perch found in the Baltic Sea has been forced to alter behaviors due to competition against Roach population. Decrease in fecundity, and growth were observed through several studies comparing the two (Lappalainen et al. 2001).*
- *The introduction of* R. rutilus *has been linked to the extinction of the Arctic Charr in Lough Corrib, alongside the severe decline in pollan numbers in Lower Lough Erne (Ferguson 2008).*
- *Arctic Charr (*Salvelinus alpinus*) has been recently impacted by eutrophication, climate change, and the growing populations of* R. rutilus. *It has been suggested that* R. rutilus *may compete with Arctic Charr in England for zooplankton (Winfield et al. 2008).*
- *After its introduction to Lake Erne, the Rudd disappeared (Cragg-Hine 1973).*
- *After the introduction of* R. rutilus *to Northern Ireland, there was a decline in the Tufted Duck (*Aythya fuligula*) populations, and it has been implicated that it was caused by competition for zoobenthos (Winfield et al. 1992).*

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in the food web)	6
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	1 √
Not significantly	0
Unknown	U

- Rutilus rutilus *could alter the trophic assemblages in portions of the Great Lakes and food webs near shore and bays will be most affected by this species according to how the invaded lakes in Ireland projected (USFWS 2012).*
- *After the introduction of* R. rutilus *to Northern Ireland, populations of the once abundant Tufted Duck,* Aythya fuligula, *experienced a decline in its population (Winfield et al. 1992). Competition for benthos is suggested to be the cause. There was an increase in the populations of a piscivorous bird, the great crested grebes (*Podiceps cristatus*), and it is thought that* R. rutilus *is a food resources for the bird.*

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1 √
Not significantly	0
Unknown	U

- Rutilus rutilus *produces fertile hybrids with* Abramis brama *(Common Bream) (Kottelat and Freyhof 2007).*
- *Neither of these species is native to the Great Lakes.*
- *Hybrids of Roach and Rudd were recorded in Lough Melvin in 2002 (Stokes et al. 2006).*

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1 √
Not significantly	0
Unknown	U

- *Water quality has been decreased in some lakes due to increased eutrophication by* R. rutilus *(Stokes et al. 2006).*
- *Increased turbidity and algal blooms have been observed in result of zooplanktons being overgrazed by Roach (Stokes et al. 2006).*
- Rutilus rutilus *has negatively impacted water quality and maintained high algal productivity in southern Finland. Bioturbation occurred when* R. rutilus *was feeding, which released nutrients from the sediments (Horppila and Kairesalo 1990).*
- *During times of low zooplankton abundance,* R. rutilus *caused high phosphorous loading and turbidity (Horppila and Kairesalo 1992).*

E6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR	6

Yes, and it has resulted in significant negative consequences for at least one native species	
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1 √
Not significantly	0
Unknown	U

- *Many studies have shown in different regions around the world a tremendous decrease in the plankton and altered macrophyte communities (USFWS 2012).*

Environmental Impact Total	**11**
Total Unknowns (U)	**0**

Scoring		
Score	# U	**Impact**
>5	Any	<u>**High**</u>
2-5	Any	Moderate
0	0-1	Low
1	0	
0	≥2	Unknown
1	≥1	

POTENTIAL SOCIO-ECONOMIC IMPACT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1
Not significantly	0 √
Unknown	U

- *There are no reported threats to humans or any other hazards, but it could be potential pest (Kottelat and Freyhof 2007).*

S2) Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6

Yes, but the costs have been small and are largely reparable or preventable	1
Not significantly	0 √
Unknown	U

S3) Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0
Unknown	U √

- Rutilus rutilus *reduce water quality in lakes by heavily grazing the zooplankton, which leads to faster eutrophication by accelerating algal blooms and causing the waters to become more turbid (Stokes et al. 2006). However, there have not been any reports of water quality degradation with respect to human use.*
- *Water quality increased when Roach was removed at a large scale in Finland (Stokes et al. 2006).*
- Rutilus rutilus *may curtail efforts to improve water quality; after initial recovery of a lake in southern Finland, algal blooms increased and it was suggested that* R. rutilus *had maintained high algal productivity and biomass (Horppila and Kairesalo 1990).*

S4) Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1 √
Not significantly	0
Unknown	U

- *Atlantic Salmon and Brown Trout are important fish on the market with high sales. Roach has reduced some abundance in Atlantic Salmon and Brown Trout, but not enough to significantly cause a negative impact on the commercial fisheries (Ferguson 2008).*
- *Rudd, another introduced species in the Great Lakes, has been forced to move in weeded areas and has been disappearing everywhere in freshwater lakes in Ireland due to* R. rutilus *(Stokes et al. 2006).*

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6
Yes, but negative consequences have been small	1 √
Not significantly	0
Unknown	U

- *Atlantic Salmon and other species that are affected by Roach are known to be used in recreational fishing, therefore they might be slightly impacted, but great damage is not likely to be seen (Ferguson 2008).*

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly	6

diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

- *There have been no reported decreases in natural values of any regions.*

Socio-Economic Impact Total	**2**
Total Unknowns (U)	**1**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	**Moderate**
0	0-1	Low
1	0	
0	≥2	Unknown
1	≥1	

POTENTIAL BENEFICIAL EFFECT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular effect. An "Unknown" response is appropriate if the potential for a particular effect might be inferred but has not been explicitly reported or if there is an unresolved debate about a particular effect.

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1
Not significantly	0 √
Unknown	U

- *Roach prefers to feed on submersed vegetation, yet no significant changes are noticed.*

B2) Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?

Yes, it is economically important to at least one of these industries	6
Yes, but its economic contribution is small	1 √
Not significantly	0

Unknown	U

- *The United States Fish and Wildlife Services (2012) reported Roach being used for live bait as well as in recreational fishing.*
- *Anglers in Ireland used Rroach as bait for Pike in the early 1990 (Stokes et al. 2006).*

B3) Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local communities and/or tourism	6
It is sometimes employed recreationally, but adds little value to local communities or tourism	1 √
Not significantly	0
Unknown	U

- *The United States Fish and Wildlife Services (2012) reported Roach being used and introduced for live bait as well as in recreational fishing.*

B4) Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR It is potentially important to medicine or research and is currently being or scheduled to be studied	1
Not significantly	0 √
Unknown	U

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1
Not significantly	0 √
Unknown	U

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1
Not significantly	0 √
Unknown	U

Beneficial Effect Total	**2**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	**<u>Moderate</u>**
0	0-1	Low
1	0	
0	≥2	Unknown
1	≥1	

Scientific Name: *Sander lucioperca*
Linnaeus, 1758

Common Name: Zander, Pikeperch, Sandart

Synonyms: *Stizostedion lucioperca*

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: Low

Hitchhiking/fouling: Low

Unauthorized intentional release: Unlikely

Stocking/planting/escape from recreational culture: Unknown

Escape from commercial culture: Unlikely

Transoceanic shipping: Unlikely

***Sander lucioperca* has a low probability of introduction to the Great Lakes (Confidence level: Moderate).**

Potential pathway(s) of introduction: Dispersal, Hitchhiking/Fouling, Unauthorized Intentional Release, Stocking

Sander lucioperca eggs may be transported on macrophytes and in substrate. *Sander lucioperca* would have to be transported from where it occurs in North Dakota to the Great Lakes (USFWS 2014e). Many think that *S. lucioperca* would benefit North American fisheries (USFWS 2014e).

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100 √
No, this species does not occur near waters connected to the Great Lakes basin and/or is not mobile or able to be transported by wind or water.	0
Unknown	U

- Sander lucioperca *occurs in North Dakota (USFWS 2014e).*

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25 √
Unknown	U

- Sander lucioperca *occurs in North Dakota (USFWS 2014e).*

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100 √
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0
Unknown	U

- Sander lucioperca *eggs may be transported on macrophytes and in substrate (FAO 2012).*

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1 √
Unknown	U

- Sander lucioperca *occurs in North Dakota (USFWS 2014e).*

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a) Is this species sold at aquarium/pet/garden stores ("brick & mortar" or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100
No, this species this species is rarely/never sold.	0 √
Unknown	U

- *Many think that* S. lucioperca *would benefit North American fisheries (USFWS 2014e). While not for sale, it would not be difficult to catch fish from North Dakota and transport them into the Great Lakes.*

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100 √
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0
Unknown	U

- *Many think that* S. lucioperca *would benefit North American fisheries (USFWS 2014e).*

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is likely to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces), this activity may occur within 20 km of the basin because of the species' popularity/value.	Score x 0.25
Unknown	U √

- Sander lucioperca *would have to be transported from where it occurs in North Dakota (USFWS 2014e).*

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100
No, this species is not commercially cultured in or transported through the Great Lakes region.	0 √

Unknown	U

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40
No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0 √
Unknown	U

- Sander lucioperca *eggs can survive salinities <5 ppm (Gröger et al. 2007).*

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5
Yes, but this species has neither been observed in ballast/fouling ships entering the Great Lakes nor in ports in direct trade with the Great Lakes.	Score x 0.1
No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0
Unknown	U

- Sander lucioperca *is cultured in Sweden (Baltic Sea) (Abdolmalaki and Psuty 2007).*
- *This fish lives in coastal marine waters (catchment areas) of Baltic Sea and North Sea (FAO 2013b).*

Vector Potential Scorecard					
Vector		**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind		**100**	x 0.25	**25**	Low
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.		**100**	x 0.1	**10**	Low
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)		**0**	x	**0**	Unlikely
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)		**100**	x U	**U**	Unknown
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)		**0**	x	**0**	Unlikely
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling		**0**	x	**0**	Unlikely
Total Unknowns (U)	**1**	**Confidence Level**		Moderate	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

ESTABLISHMENT POTENTIAL RESULTS

Status: **Established in North America, but not the Great Lakes**

***Sander lucioperca* has a high probability of establishment if introduced to the Great Lakes (Confidence level: High).**

Sander lucioperca have a tolerance for a wide range of salinities, water temperatures, and nutrient loads. They are already found in locations in Europe with more extreme temperatures and salinities than the Great Lakes which suggest that it would survive winter temperatures if introduced into the Great Lakes. *S. lucioperca* have demonstrated an ability to adapt to available prey sources. In other introduced lakes, *S. lucioperca* has become a top predator. This species is a nest guarder which offers it an advantage over other native fish that do not guard young.

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
	8

- S. lucioperca *lives in freshwater and brackish water with salinities <12 ppm (Abdolmalaki and Psuty 2007).*
- *This species inhabits water with temperatures ranging from <4-30°C (Çelik et al. 2005).*
- S. lucioperca *prefer deep, calm, temperate waters. This species is found in both clear and turbid waters but requires a high oxygen concentration (FAO 2012).*
- *This species inhabits productive, eutrophic waters in Europe (Kangur et al. 2007a).*
- *The preferred temperature for this species is 24-29°C (Hokanson 1977).*
- S. lucioperca *can tolerate salinities 29-32 psu after a gradual increase over 6 hours (Brown et al. 2001).*

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9
Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0

Unknown	U
	8

- *This species has high abundance in Egirdir Lake (Turkey), which freezes over in January, and has water temperatures 4-5°C in December and February (Çelik et al. 2005).*
- S. lucioperca *inhabits Estonian lakes that are frozen November-April, and which may have an oxygen deficit under the ice (Kangur et al. 2007).*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
	8

- S. lucioperca *consumes arthropods (including isopods and insects) and fish (including cyprinids, percids, and salmonids) (Argillier et al. 2012).*
- *This species consumes zooplankton when young (Gröger et al. 2007).*
- *Pikeperch can change their prey selection relatively rapidly in response to changes in the abundance and vulnerability of prey species (Popova 1978).*
- *This species can adapt a planktivore diet during the first year if fish prey aren't available, i.e., adapts an optimal foraging strategy (Persson and Brönmark 2008).*

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	0
Unknown	U
	7

- *Egirdir Lake is the second biggest natural fresh water lake in Turkey.* S. lucioperca *was stocked into Egirdir Lake in 1955. Other carp species evidently decreased and some species became extinct while* S. lucioperca *population increased in subsequent years. Eventually, only carp,* S. lucioperca*, and crayfish fishing in the lake had commercial value (Çelik et al. 2005).*

- S. lucioperca *is a top predator in introduced habitats (France), i.e., preys on other predators (Kopp et al. 2009).*

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
	7

- *The relative fecundity of this species averages between 150 and 400 eggs (Lappalainen et al. 2003).*
- S. lucioperca *has greater fecundity than walleye (Smith et al. 1998).*
- *European percids have total fecundity of 3000-1,185,000; maximum total fecundity of* S. lucioperca *recorded as 2,500,000 (Collette et al. 1977).*

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
	7

- S. lucioperca *is a nest guarder.*

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6

Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	9

- S. lucioperca *has a very high climate match (USFWS 2014e).*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- *This species is favored in turbid waters, as they have visual adaptations to enhance foraging capacity (Ali et al. 1977, Karås and Sandström 2002).*
- *Reproduction is impacted in high pollution*: *Total suspended solids in concentrations even below 25 mg · dm-3 (the generally accepted threshold level) were found to inhibit fish embryogenesis by affecting fertilisation (% fertilisation: untreated, filtered riverine water and tap water: 75; 91; 85, respectively), perivitelline space formation, organogenesis, and hatching. The total suspended solids were also found to affect the larval size: the larvae hatched in water containing suspended particulates were smaller than those hatched in clean water; the larval malformation rate was higher in the suspended solids-rich water than in clean water (Bonisławska 2011).*
- S. lucioperca *inhabits water with temperatures from <4-30°C (Çelik et al. 2005).*
- S. lucioperca *prefers deep, calm, temperate waters. This species are found in both clear and turbid waters but require a high oxygen concentration (FAO 2012).*
- *Inhabits productive, eutrophic waters in Europe (Kangur et al. 2007b).*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0
Unknown	U
	8

- *Reproduction can occur in deep water, this species does not need macrophytes (Laurent et al. 1973).*

- *This species can inhabit a range of conditions: reservoirs with primarily artificial substrate with little habitat diversity and deep oligotrophic waters, and also shallow eutrophic reservoirs with macrophyte growth (Argillier et al. 2012).*
- *Within suitable habitat this species uses different microhabitats during different seasons. In the autumn they prefer waters with a depth of 1.2-1.8 m with a substrate made of large pebbles. They then move to much deeper waters where they spend the winter. Following this they migrate to shallower waters with a gravel/pebble substrate for spawning. Habitat preferences are more varied in the summer. Optimal conditions for egg development: water temperature between 12-20°C; high oxygen concentration (> 4.5 mg O2/l); low salinity <5 ppm (FAO 2012).*
- *The spawning behaviour, nest building, guarding and care taking of the eggs has enabled the Pikeperch to expand its spawning sites into less oxygenated waters with silted or muddy bottoms (Balon et al. 1977).*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0
Unknown	U
	9

- *Successive year-class strengths and growth rates in northern environments are also likely to increase as temperatures increase. Increases in both abundance and size are likely (Wrona et al. 2010).*
- S. lucioperca *can reproduce in salinity of <5ppm, increased salinization my favor this species over natives.*

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
	9

- S. lucioperca *consumes arthropods (including isopods and insects) and fish (including cyprinids, percids, and salmonids) (Argillier et al. 2012).*
- *Pikeperch can change their prey selection relatively rapidly in response to changes in the abundance and vulnerability of prey species (Popova 1978).*
- *This species can adapt a planktivore diet during the first year if fish prey aren't available, i.e., adapts an optimal foraging strategy (Persson and Brönmark 2008).*

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Great Lakes and is not likely to be introduced	-80% total points (at end)
Unknown	U
	9

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes)	6
Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0

Unknown	U
	6

- *Ruffe was the main prey item for* S. lucioperca *in a large lake in Estonia (Kangur et al. 2007b).*

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0
Unknown	U
	0

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9
Frequent, moderate inocula	6
Frequent, small inocula OR infrequent, large inocula	3
Infrequent, small or moderate inocula	0
Unknown	U
	U

- *This would depend on intentional movement for stocking purposes, or unintentional movement of eggs via recreational boats.*

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
	6

- *This species is native to the Caspian watershed, and in the basins of the Black, Azov, Aral and Baltic Seas (Craig 2000).*
- *Introduced into France, Finland (Archipelago Sea, Baltic Sea), Spain, Azores Islands, Belgium, Croatia, Denmark, Italy, Netherlands, Portugal, Slovenia, Switzerland, United Kingdom) and a range of other countries (Algeria, China, Kyrgyzstan, Morocco, Tunisia, Turkey, USA) (Argillier et al. 2012, Clavero and Garcia-Berthou 2006, FAO 2012).*
- *Although it was thought that* S. lucioperca *stocked into a North Dakota lake for sport fishing did not survive (Anderson 1992b), the capture of a fish in August 1999, and another 2+ year old fish in 2000 shows that at least some survived and reproduced. Five young-of-the-year fish were collected in 2005. As of 2009, the state reports that they are established in Spiritwood Lake. The North Dakota Game and Fish Department reports capture of yearlings and 2-year olds, although they [say] the population is very small. Genetic sampling of fish has found that all are pure zander, there has been no hybridization. Spiritwood Lake is normally a closed basin, however it did flood several years ago (1998-2001) (USFWS 2014e).*

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
	7

- *Pikeperch populations spread easily and can colonize neighboring waters provided there is relatively good access (Linfield and Rickards 1979).*
- *This species was introduced to a single canal in France in 1912, has since spread to most part of the hydrographic network (Argillier et al. 2012).*

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing the establishment and spread of this species)	-90% total points (at end)

Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent the establishment and/or spread of this species	0
Unknown	U
	0

Establishment Potential Scorecard				
Points	**Probability for Establishment**	A. Total Points (pre-adjustment)		116
>100	High	**Adjustments**		
		B. Critical species	A*(1- 0%)	116
51-99	Moderate	C. Natural enemy	B*(1- 0%)	116
		Control measures	C*(1- 0%)	116
0-50	Low	**Potential for Establishment**		High
# of questions answered as "unable to determine"	**Confidence Level**			
0-1	High	Total # of questions unknown		1
2-5	Moderate			
6-9	Low	Confidence Level		High
>9	Very low			

Section C: Potential for Impact

<u>IMPACT POTENTIAL RESULTS</u>

Environmental: High

Socio-Economic: Unknown

Beneficial: High

***Sander lucioperca* has the potential for high environmental impact if introduced to the Great Lakes.**

When *S. lucioperca* was stocked into Egirdir Lake in 1955, other carp species evidently decreased and some species became extinct while *S. lucioperca* population increased in subsequent years. Eventually, only carp, *S. lucioperca*, and crayfish fishing in the lake had commercial value (Çelik et al. 2005). *S. lucioperca* can prey upon Brown Trout and Perch. This raises questions about the impact of *S. lucioperca* introduction, which is suspected of being significant, on the stocks and exploitation of native species (Cowx 1997, Kershner et al. 1998, Smith et al. 1996, Smith et al. 1998).

Current research on the potential for socio-economic impacts to result from *Sander lucioperca* if introduced to the Great Lakes is inadequate to support proper assessment.

There is insufficient information available to determine how *Sander lucioperca* would impact socio-economics in the Great Lakes region. *S. lucioperca* is a top predator of Brown Trout, Perch and salmonids, and as such could impact commercial fisheries for these species. However, it is not known to what extent *S. lucioperca* could affect these commercial fisheries.

***Sander lucioperca* has the potential for high beneficial impact if introduced to the Great Lakes.**

S. lucioperca has been commercially valuable since the 1920s, when it constituted about one-third of the total taken from the southern Caspian Sea. Due to overfishing and habitat degradation, it declined and has remained at low levels. In 2009, annual aquaculture production of Pikeperch exceeded 100 tonnes in three countries: Denmark, Tunisia and Ukraine. Total Pikeperch production in aquaculture (653 tonnes) in 2009 was less than 5 percent of the level caught in open waters (14,739 tonnes). Stocking can yield the equivalent of an annual interest rate of 43% (based on capital invested in the stocked young of the year fish) (Hansson et al. 1997). A popular angling fish, with highly desired meat (Larsen and Berg 2011).

POTENTIAL ENVIRONMENTAL IMPACT

NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1 √
Not significantly	0
Unknown	U

- *Brabrand and Faafeng (1993) showed how young Roach shifted from pelagic to littoral habitats as a result of* S. lucioperca *introduction in a Norwegian lake. An indirect effect of the changed behaviour of Roach was increased infection rate of Roach with the ectoparasite* Ichthyophthirius multifiliis*, as Roach was more often exposed to the free swimming state of* Ichthyophthirius multifiliis *when living in shallow water near the substrate compared to their previously more pelagic lifestyle (Brabrand et al. 1994).*

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1 √
Not significantly	0
Unknown	U

- *Egirdir Lake is the second biggest natural fresh water lake in Turkey.* S. lucioperca *was stocked into Egirdir Lake in 1955. Other carp species evidently decreased and some species became extinct while* S. lucioperca *population increased in subsequent years. Eventually, only carp,* S. lucioperca*, and crayfish fishing in the lake had commercial value (Çelik et al. 2005).*
- S. lucioperca *is a top predator in introduced habitats (France), i.e., preys on other predators (Kopp et al. 2009).*

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in the food web)	6 √
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	1
Not significantly	0
Unknown	U

- S. lucioperca *can prey upon Brown Trout and Perch. This raises questions about the impact of* S. lucioperca *introduction, which is suspected of being significant, on the stocks and exploitation of native species (Cowx 1997, Kershner et al. 1999, Smith et al. 1996, Smith et al. 1998)..*
- S. lucioperca *is a top predator in introduced habitats (France), i.e., preys on other predators (Kopp et al. 2009).*
- *Schulze et al. (2006) found that the Perch (*Perca fluviatilis*) population in a shallow, mesotrophic lake with natural occurrence of Perch and Pike (*Esox lucius*) were negatively affected by* S. lucioperca *introduction. In an experiment they showed that Perch was forced away from its preferred habitat, the pelagic zone, by* S. lucioperca.
- *Jeppesen et al. (2001) found evidence of reduced population densities of cyprinids in a paleolimnologic study in the Danish Lake Skanderborg, where* S. lucioperca *was introduced in 1903-04. After this a permanent reduction in cyprinid densities was found.*
- *Cowx (1997) found that introducing* S. lucioperca *to English rivers created a crash in the cyprinid fish community.*
- *In the Turkish Lake Egredir,* S. lucioperca *was introduced in 1955 and from 1961 it became an important species in commercial fisheries in the lake. The introduction also had the result that 5 out of 9 indigenous fish species disappeared, among these three species of Phoxinellus, two of which were endemic to Lake Egredir (Crivelli 1995). Consequently these two species must now be considered extinct worldwide.*
- *Denmark has shown that predation on smolts in the lower part of the river has an adverse effect on the population of sea-trout (Koed et al. 2002).*

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0 √
Unknown	U

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1
Not significantly	0 √
Unknown	U

E6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1
Not significantly	0 √
Unknown	U

Environmental Impact Total	**8**
Total Unknowns (U)	**0**

Scoring		
Score	# U	**Impact**
>5	Any	**<u>High</u>**
2-5	Any	Moderate

<table>
<tr><td>0</td><td>0-1</td><td rowspan="2">Low</td></tr>
<tr><td>1</td><td>0</td></tr>
<tr><td>0</td><td>≥2</td><td rowspan="2">Unknown</td></tr>
<tr><td>1</td><td>≥1</td></tr>
</table>

POTENTIAL SOCIO-ECONOMIC IMPACT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1
Not significantly	0 √
Unknown	U

S2) Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1
Not significantly	0 √
Unknown	U

S3) Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0 √
Unknown	U

S4) Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0

Unknown	U √

- *This species is a top predator of Brown Trout, Perch and salmonids, and as such could impact commercial fisheries for these species.*

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6
Yes, but negative consequences have been small	1
Not significantly	0
Unknown	U √

- *This species is a top predator of Brown Trout, Perch and salmonids, and as such could impact recreational fisheries for these species.*

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

Socio-Economic Impact Total	**0**
Total Unknowns (U)	**2**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	Low
1	0	Low
0	≥2	**Unknown**
1	≥1	**Unknown**

POTENTIAL BENEFICIAL EFFECT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular effect. An "Unknown" response is appropriate if the potential for a particular effect might be inferred but has not been explicitly reported or if there is an unresolved debate about a particular effect.

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1
Not significantly	0
Unknown	U √

- *Ruffe was the main prey item for* S. lucioperca *in a large lake in Estonia (Kangur et al. 2007b).*

B2) Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?

Yes, it is economically important to at least one of these industries	6 √
Yes, but its economic contribution is small	1
Not significantly	0
Unknown	U

- S. lucioperca *has been commercially valuable since the 1920s, when it constituted about one-third of the total taken from the southern Caspian Sea. Due to overfishing and habitat degradation, it declined and has remained at low levels. In 1990, the Iranian government initiated a* S. lucioperca *stock enhancement program (Abdolmalaki and Psuty 2007).*
- *In 2009, annual aquaculture production of pike-perch exceeded 100 tonnes in three countries - Denmark, Tunisia and Ukraine. Total Pike-perch production in aquaculture (653 tonnes) in 2009 was less than 5 percent of the level caught in open waters (14,739 tonnes). Wholesale prices for Pike-perch fluctuate significantly but usually range from USD 5.6-12.5/kg (whole fish) with a mean of about ~USD 8.3/kg. In some countries, such as Germany and France, prices can be as high as USD 22.2/kg (FAO 2013b).*
- *Thanks to its low fat content (usually 1-2%) and highly assimilable protein, pike-perch meat is highly valued by dieticians (FAO 2013b).*
- *Stocking can yield the equivalent of an annual interest rate of 43% (based on capital invested in the stocked young of the year fish) (Hansson et al. 1997).*

B3) Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local communities and/or tourism	6 √
It is sometimes employed recreationally, but adds little value to local communities or tourism	1
Not significantly	0
Unknown	U

- *This species is a popular angling fish, with highly desired meat (Larsen and Berg 2011).*
- *Thanks to its low fat content (usually 1-2%) and highly assimilable protein, pike-perch meat is highly valued by dieticians (FAO 2013b).*

B4) Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR It is potentially important to medicine or research and is currently being or scheduled to be studied	1
Not significantly	0 √
Unknown	U

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1
Not significantly	0 √
Unknown	U

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1
Not significantly	0 √
Unknown	U

Beneficial Effect Total	**12**
Total Unknowns (U)	**1**

Scoring		
Score	# U	**Impact**
>5	Any	<u>**High**</u>
2-5	Any	Moderate
0	0-1	Low
1	0	
0	≥2	Unknown
1	≥1	

Scientific Name: ***Silurus glanis***
Linnaeus, 1758

Common Name: Wels Catfish, Sheatfish, European Catfish

Synonyms:

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: Unlikely

Hitchhiking/fouling: Unlikely

Unauthorized intentional release: Unknown

Stocking/planting/escape from recreational culture: Unlikely

Escape from commercial culture: Unlikely

Transoceanic shipping: Unlikely

***Silurus glanis* has an unknown/low probability of introduction to the Great Lakes (Confidence level: Moderate).**

Potential pathway(s) of introduction: Unauthorized Intentional Release

Siluris glanis is the largest freshwater fish in the world. *Silurus glanis* is reportedly robust to transport (Copp et al. 2009) but it is uncertain whether it is available for sale in the United States.

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100
No, this species does not occur near waters connected to the Great Lakes basin and/or is not mobile or able to be transported by wind or water.	0 √
Unknown	U

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1

This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0 √
Unknown	U

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a) Is this species sold at aquarium/pet/garden stores ("brick & mortar" or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100
No, this species this species is rarely/never sold.	0
Unknown	U √

- *Several hobbyist forums included posts by individuals seeking this fish, and one indicated they had Wels Catfish for sale in the United States (http://www.monsterfishkeepers.com/forums/showthread.php?224509-Wels-Catfish-anyone-in-the-US-get-one). However, these claims cannot be verified, so this vector remains unknown. It is being sold in Europe (e.g., http://www.homersfieldlake.com/Fish_Farm.html).*

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1

This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1
Unknown	U √

- *Several hobbyist forums included posts by individuals seeking this fish, and one indicated they had Wels Catfidh for sale in the United States (http://www.monsterfishkeepers.com/forums/showthread.php?224509-Wels-Catfish-anyone-in-the-US-get-one). However, these claims cannot be verified, so this vector remains unknown. It is being sold in Europe (e.g., http://www.homersfieldlake.com/Fish_Farm.html).*

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0 √
Unknown	U

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is likely to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces), this activity may occur within 20 km of the basin because of the species' popularity/value.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100
No, this species is not commercially cultured in or transported through the Great Lakes region.	0 √
Unknown	U

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40
No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0 √
Unknown	U

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5
Yes, but this species has neither been observed in ballast/fouling ships entering the Great Lakes nor in ports in direct trade with the Great Lakes.	Score x 0.1
No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0
Unknown	U

Vector Potential Scorecard					
Vector		**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind		**0**	x	**0**	Unlikely
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.		**0**	x	**0**	Unlikely
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)		**U**	x U	**U**	Unknown
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)		**0**	x	**0**	Unlikely
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)		**0**	x	**0**	Unlikely
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling		**0**	x	**0**	Unlikely
Total Unknowns (U)	**2**	**Confidence Level**		Moderate	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

ESTABLISHMENT POTENTIAL RESULTS

Status: Not established in North America, including the Great Lakes

***Silurus glanis* has a moderate probability of establishment if introduced to the Great Lakes (Confidence level: High).**

It is likely *S. glanis* would be able to survive in the Great Lakes since it tolerates a range of climates including many of the conditions found in the Great Lakes. Wels Catfish is able to adjust its diet based on availability of prey making it adaptable to Great Lakes food webs. This species is a nest guarder which gives it an advantage over other native fish that do not nest guard young.

This species would only be introduced through intentional release or escape from a stocked pond. However, this species is difficult to purchase in the United States, so these would be infrequent occurrences.

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
	8

- S. glanis *survives water temperatures 0-27°C, though success may be limited in lower water temperatures (Britton et al. 2007, David 2006).*
- *This species spawns at 18-22°C (Copp et al. 2009)*
- S. glanis *tolerates salinity up to 15 ppm (Copp et al. 2009).*
- *This species can inhabit eutrophic and turbid waters (Castaldelli et al. 2013).*
- *Wels Catfish is able to withstand prolonged periods of hypoxia (Massabuau and Forgue 1995).*

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9
Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
	8

- S. glanis *inhabits waters 0-5°C (Britton et al. 2007).*
- *This species is able to withstand prolonged periods of hypoxia (Massabuau and Forgue 1995), due to high levels of hemoglobin (Copp et al. 2009).*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
	9

- *In a study performed by Carol (2009) Wels Catfish diet depended on site and catfish size. Catfish measuring less than 30 cm consumed mostly invertebrates, thereafter shifting to Red Swamp Crayfish (*Procambarus clarkia*) (old introductions) or fish (recent introductions). A number of fish species were present in stomachs but Common Carp (*Cyprinus carpio*) and birds were only present in very large fish (> 120 cm.*
- *It is well documented that Wels Catfish take advantage of its diet plasticity and ability to prey upon the most abundant available species of a suitable size within its habitat (Carol 2009, Castaldelli et al. 2013, Martino et al. 2011, Syväranta et al. 2010)..*

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	0
Unknown	U
	7

- *There is limited data, but Wels Catfish is considered abundant where introduced on the Iberian peninsula (Carol et al. 2007).*
- *In the Po River basin in 1991, Wels Catfish accounted for 6.1% of the total biomass. With optimal foraging conditions, abundant prey, and few competitors, it reached 77%, 71%, and 62% of the overall biomass in 1997, 2003, and 2009, respectively (Castaldelli et al. 2013).*
- *This species has remained rare in the River Thames (Copp 2007).*

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
	3

- *The absolute fecundity of female* S. glanis *ranges from 14 600 to 354 000 eggs (Copp et al. 2009).*
- *Relative fecundity (eggs per kg body weight) of siluroid species is as follows (Legendre et al. 1996):*
    - Silurus glunis*: 10,000-25,000*
    - Guleichthys feliceps*: 50,000*
    - lctalurus punctutus*: 8,000*
    - Chtysichthys nigrodigitaius*: 15,000-18,000*
    - Hoplosternum littorale*: 45,000-75,000*
    - Clarias gariepinus*: 60,000-150,000*
    - Clarias macrocephalus*: 20,000-50,000*
    - Heterobranchus longifilis*: 30,000-120,000*
    - Pseudoplatystoma coruscans*: 120,000-130,000*

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
	3

- S. glanis *is a nest guarder (Copp et al. 2009).*

<u>ENVIRONMENTAL COMPATIBILITY</u>

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6

Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	6

- S. glanis *native distribution extends from Germany eastwards through to Poland, up to Southern Sweden and down to Southern Turkey and north Iran stretching through the Baltic States to Russia (Greenhalgh 1999) and to the Aral Sea of Kazakhstan and Uzbekistan (Copp et al. 2009, Phillips and Rix 1988)..*
- *This range of climates include many of the conditions found in the Great Lakes.*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	6

- *High levels of hemoglobin also make Wels Catfish relatively tolerant of pollution (Lelek 1987).*
- *This species has a well-developed non-visual sensors make it well adapted to waters with low visibility (Copp et al. 2009).*
- S. glanis *survives water temperatures 0-27°C, though success may be limited in lower water temperatures (Britton et al. 2007, David 2006).*
- *This species can inhabit eutrophic and turbid waters (Castaldelli et al. 2013).*
- *Wels Catfish is also able to withstand prolonged periods of hypoxia (Massabuau and Forgue 1995).*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0
Unknown	U
	6

- S. glanis *inhabits the lower reaches of large rivers and muddy lakes (Alp et al. 2011)*
- *Wels Catfish individuals are usually strongly associated with areas with a high density of woody debris, boulders, low flow and tree roots (Abdullayev et al. 1978). The species, therefore, appears to prefer large water bodies with cryptic habitat (Britton et al. 2007).*

- *Wels Catfish has thrived in degraded habitats (Italy), i.e., canals that were eutrophic and turbid, without morphological complexity, and with sparse vegetation (Castaldelli et al. 2013).*
- *The species is normally encountered throughout their range in large rivers, lakes and coastal areas of low salinity (<15 ppm). Primarily a fish of rich, weedy lakes and slow, deep lowland rivers, in its native range, the species is known to shift during their first year of life into mid channel habitats (Wolter and Vilcinskas 1996, Wolter and Freyhof 2004), which are important for reproduction and habitat partitioning between different age groups (Wolter and Bischoff 2001). However, the preferred habitat of* S. glanis *is still waters (Greenhalgh 1999, Wheeler 1969). During winter, it hibernates in rivers in deep holes, dens and crevices in the bed; in lakes, it lies in the lower third of the water column or on soft mud (Copp et al. 2009, Lelek et al. 1964, Lelek 1987)..*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0
Unknown	U
	7

- S. glanis *maximum growth occurs at 25-27°C, so warming waters would benefit this species (David 2006).*
- *It can withstand low salinity, so it may be able to outcompete native species limited to freshwater if salinization increases (Copp et al. 2009).*

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
	8

- *This species consumes whatever is most abundant, from crustaceans to fish (Castaldelli et al. 2013).*

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Great Lakes and is not likely to be introduced	-80% total points (at end)
Unknown	U
	9

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes)	6
Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0
Unknown	U
	0

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0
Unknown	U
	0

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9
Frequent, moderate inocula	6
Frequent, small inocula OR infrequent, large inocula	3
Infrequent, small or moderate inocula	0
Unknown	U
	0

- *This species would only be introduced through intentional release, or escape from a stocked pond. However, this species is difficult or impossible to purchase in the US, so these would be infrequent occurrences.*

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U

	7

- *Wels Catfish is native to eastern Europe and western Asia. This species has been introduced to many European countries, including France, Italy, the Netherlands, Spain and the United Kingdom due to its popularity among anglers (Alp et al. 2011, Bănărescu 1989, Britton et al. 2007, Carol et al. 2007, Carol 2009, Copp et al. 2009, Krieg et al. 2000). This includes intentional, unauthorized introduction (Pérez-Bote 2009).*
- *This species is farmed in Austria, Bulgaria, Croatia, Czech Republic, France, Hungary, Greece, Macedonia, Poland, and Romania (Linhart et al. 2002)*

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
	6

- *This species has spread rapidly though human introductions, but slowly via natural dispersal (Copp et al. 2009).*

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing the establishment and spread of this species)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent the establishment and/or spread of this species	0
Unknown	U
	0

Establishment Potential Scorecard			
Points	**Probability for Establishment**	A. Total Points (pre-adjustment)	93

>100	High	**Adjustments**		
		B. Critical species	A*(1- 0%)	93
51-99	Moderate	C. Natural enemy	B*(1- 0%)	93
		Control measures	C*(1- 0%)	93
0-50	Low	**Potential for Establishment**		Moderate
# of questions answered as “unable to determine”	**Confidence Level**			
0-1	High	Total # of questions unknown		0
2-5	Moderate			
6-9	Low	Confidence Level		High
>9	Very low			

Section C: Potential for Impact

IMPACT POTENTIAL RESULTS

Environmental: High

Socio-Economic: Low

Beneficial: High

***Silurus glanis* has the potential for high environmental impact if introduced to the Great Lakes.**

S. glanis has an association with several parasites that can have an impact on wild populations.

In early stage invasion sites, *S. glanis* mainly consumed fish because of a high abundance of small cyprinid species, such as Roach and Bleak (Carol et al. 2007). In contrast, crayfish was the main prey of Wels Catfish in advanced stage invasion sites and the ontogenetic shift to piscivory was delayed until the catfish grew larger. Accordingly, these advanced stage invasion reservoirs had size structures dominated by larger sizes of Common Carp. Although further data are needed to see how frequent these patterns are, results from Carol (2009) strongly suggest that at the early stages of invasion, catfish grow faster and are in better condition because they prey more on fish. As invasion proceeds, however, the catfish reduce fish numbers, particularly of smaller fish, indirectly favoring crayfish and eventually resulting in their own reduced growth rates (Carol 2009).

In addition to fish prey, another likely ecological impact of Wels Catfish is on some groups of waterbirds, especially in the Anatidae family. Few birds have been observed in the catfish stomach contents (Czarnecki et al. 2003, Omarov and Popova 1985). Carol (2009) also found that waterbird abundance varied significantly with the invasion sequence (advance stage correlated with lower bird abundance) and this was not due to correlation or confounding with abiotic factors (such as reservoir size, altitude or trophic state) (Carol 2009). The significantly lower abundance of waterbirds in reservoirs with Wels

Catfish could be due to either a direct ecological impact (predation) by Wels Catfish and/or to avoidance behavior by waterbirds to reduce predation risk (Carol 2009).

It is well documented that Wels Catfish take advantage of its diet plasticity and ability to prey upon the most abundant available species of a suitable size within its habitat (Carol 2009, Martino et al. 2011, Syväranta et al. 2010). Wels Catfish may adapt foraging behaviors in new habitats and introduced populations have started breaching onto shores to capture birds on land (Cucherousset et al. 2012, Syväranta et al. 2010).

There is little or no evidence to support that *Silurus glanis* has the potential for significant socio-economic impacts if introduced to the Great Lakes.

It has not been reported that *Silurus glanis* poses a threat to human health or water quality. There is no evidence that this species negatively impacts infrastructure, economic sectors, recreational activities and associated tourism, or the aesthetic appeal of the areas it inhabits.

***Silurus glanis* has the potential for high beneficial impact if introduced to the Great Lakes.**

The Wels Catfish has an economic importance in commercial and recreational fisheries as well as in aquaculture. Its aquaculture production has increased from 600 tonnes in 1993 to 2,000 tonnes in 2002 in ten European countries (Copp et al. 2009, Linhart et al. 2002). *Silurus glanis* is considered a delicacy in some countries (Hungary, Poland, Slovakia, Lithuania), where it is exploited for its flesh (tender white meat), skin (for leather and glue production), and eggs (for caviar) (Copp et al. 2009). The popularity of *S. glanis* relates to the large sizes they can reach; they are perceived as an attractive big-game species by many United Kingdom anglers (Hickley and Chare 2004).

POTENTIAL ENVIRONMENTAL IMPACT

NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1
Not significantly	0
Unknown	U √

- S. glanis *has several associated parasites (Copp et al. 2009):*
    - *Myxobolidae can have a significant pathological impact on wild and cultured fishes, and such episodes are often preceded by environmental stressors such as oxygen depletion of the water (Lom and Dykova 1992).*
    - *Acanthocephalans (e.g.* L. plagicephalus*) can cause extensive damage such as lesions to the intestinal tract of fish where they attach leading secondarily to infections by bacteria (Dezfuli et al. 1990).*

- *High intensities of parasitic crustaceans such as* Ergasilus sieboldi *can inflict severe damage to the gills (Dezfuli et al. 2003) resulting in large scale mortalities of fish (Kabata 1979).*

- *Further introductions of* S. glanis *may extend the distribution of specialist species such as* Trichodina siluri, M. miyarii, L. plagicephalus *and* Pseudotracheliastes stellifer*, the latter of which may have pathogenic potential as its congener,* P. stellatus*, is known to be pathogenic to sturgeons (Bauer et al. 2002, Copp et al. 2009).*
- *European sheatfish virus (ESV) is known to affect* S. glanis *only, though little work has been done to establish the susceptibility of other species. ESV was identified by Copp et al. (2009) as the pathogen of most concern.*

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1
Not significantly	0 √
Unknown	U

- *No evidence of competition was found.*

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in the food web)	6 √
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	1
Not significantly	0
Unknown	U

- *The differences in condition and growth rates between recent and older introductionsof Wels Catfish may be related to diet. In early stage invasion sites, Wels Catfish mainly consumed fish because of a high abundance of small cyprinid species, such as Roach and Bleak (Carol et al. 2007). In contrast, crayfish was the main prey of Wels Catfish in advanced stage invasion sites and the ontogenetic shift to piscivory was delayed until the catfish grew larger. Accordingly, these advanced stage invasion reservoirs had size structures dominated by larger sizes of Common Carp. Although further data are needed to see how frequent these patterns are, our results strongly suggest that at the early stages of invasion, catfish grow faster and are in better condition because they prey more on fish. As invasion proceeds, however, the catfish reduce fish numbers, particularly of smaller fish, indirectly favoring crayfish and eventually resulting in their own reduced growth rates (Carol 2009).*
- *In addition to fish prey, another likely ecological impact of catfish is on some groups of waterbirds, especially in the Anatidae family. Few birds have been observed in the catfish stomach contents (Czarnecki et al. 2003, Omarov and Popova 1984). Carol (2009) found that waterbird abundance varied significantly with the invasion sequence (advance stage correlated with lower bird abundance) and this was not due to correlation or confounding with abiotic factors (e.g. reservoir size, altitude or trophic state) (Carol 2009). The significantly lower abundance of waterbirds in reservoirs with catfish could be due to either a direct ecological impact (predation) by Wels Catfish and/or to avoidance behavior by waterbirds to reduce predation risk (Carol 2009).*

- *Data from Castaldelli et al. (2013) showed a clear temporal gradient in fish community structure. After the establishment of the exotic predator* Silurus glanis*, some native species significantly declined in abundance and biomass (i.e.* Alburnus arborella *and* Scardinius erythrophthalmus*) or disappeared (i.e.* Rutilus aula *and* Tinca tinca*). It is well documented that Wels Catfish takes advantage of its diet plasticity and ability to prey upon the most abundant available species of a suitable size within its habitat (Carol 2009, Martino et al. 2011, Syväranta et al. 2010). This may have contributed to the sequence of the decline in species. Among the most abundant native species in 1991, Tench and Italian Red-eye Roach were the first to disappear, with none captured in 2003. These are small fish with a marked benthic lifestyle. The population of Italian Bleak and Rudd, which differ from the abovementioned species in having fewer marked benthic traits, decreased more slowly, and they were still present in 2009, although greatly reduced (Castaldelli et al. 2013).*
- *Wels Catfish may adapt foraging behaviors in new habitats, e.g., introduced populations have started breaching onto shores to capture birds on land (Cucherousset et al. 2012, Syväranta et al. 2010).*

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0 √
Unknown	U

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1
Not significantly	0 √
Unknown	U

E6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1
Not significantly	0 √
Unknown	U

Environmental Impact Total	**6**
Total Unknowns (U)	**1**

Scoring		
Score	# U	**Impact**
>5	Any	<u>**High**</u>
2-5	Any	Moderate
0	0-1	Low
1	0	
0	≥2	Unknown
1	≥1	

<u>POTENTIAL SOCIO-ECONOMIC IMPACT</u>

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1
Not significantly	0 √
Unknown	U

S2) Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1
Not significantly	0 √
Unknown	U

S3) Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6

Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0 √
Unknown	U

S4) Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

Socio-Economic Impact Total	**0**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**Low**

1	0	
0	≥2	Unknown
1	≥1	

POTENTIAL BENEFICIAL EFFECT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular effect. An "Unknown" response is appropriate if the potential for a particular effect might be inferred but has not been explicitly reported or if there is an unresolved debate about a particular effect.

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1 √
Not significantly	0
Unknown	U

- S. glanis *has been introduced to regulate cyprinid fish numbers in the Netherlands, where it escaped and dispersed to other waters (Copp et al. 2009).*

B2) Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?

Yes, it is economically important to at least one of these industries	6 √
Yes, but its economic contribution is small	1
Not significantly	0
Unknown	U

- *The Wels Catfish has an economic importance in commercial and recreational fisheries as well as in aquaculture. Its aquaculture production has increased from 600 tonnes in 1993 to 2,000 tonnes in 2002 in ten European countries (Copp et al. 2009, Linhart et al. 2002).*
- *This species is considered a delicacy in some countries (e.g. Hungary, Poland, Slovakia, Lithuania), where it is exploited for its flesh (tender white meat), skin (for leather and glue production) and eggs (for caviar) (Copp et al. 2009).*

B3) Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local communities and/or tourism	6
It is sometimes employed recreationally, but adds little value to local communities or tourism	1 √
Not significantly	0
Unknown	U

- *The popularity of* S. glanis *relates to the large sizes they can reach; they are perceived as an attractive big-game species by many United Kingdom anglers (Hickley and Chare 2004).*

- *Not a species of interest in Italy (Castaldelli et al. 2013).*

B4) Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR It is potentially important to medicine or research and is currently being or scheduled to be studied	1
Not significantly	0 √
Unknown	U

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1
Not significantly	0 √
Unknown	U

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1
Not significantly	0 √
Unknown	U

Beneficial Effect Total	**8**
Total Unknowns (U)	**0**

Scoring		
Score	# U	**Impact**
>5	Any	**<u>High</u>**
2-5	Any	Moderate
0	0-1	Low
1	0	

0	≥2	Unknown
1	≥1	

Scientific Name: *Syngnathus abaster* Risso, 1827

Common Name: Black-striped Pipefish, Shortsnouted Pipefish

Synonyms:

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: Unlikely

Hitchhiking/fouling: Unlikely

Unauthorized intentional release: Unlikely

Stocking/planting/escape from recreational culture: Unlikely

Escape from commercial culture: Unlikely

Transoceanic shipping: Moderate

***Syngnathus abaster* has a moderate probability of introduction to the Great Lakes (Confidence level: High).**

Potential pathway(s) of introduction: Transoceanic Shipping

Ballast water exchange is predicted to have a low effectiveness for *Syngnathus abaster*, as it has high salinity tolerances (Snyder et al. 2014). This suggests that it could survive transportation via ballast water for introduction into the Great Lakes. This species is not extremely abundant so the frequency of ballast uptake is likely small.

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100
No, this species does not occur near waters connected to the Great Lakes basin and/or is not mobile or able to be transported by wind or water.	0 √
Unknown	U

- *The original* S. abaster *distribution area includes coastal habitats and the lower reaches of rivers of the Caspian, Azov, Black, and Mediterranean Sea basins, as well as the Atlantic coast from Gibraltar to the southern Bay of Biscay (Kottelat and Freyhof 2007). During the 20th century, this fish species expanded its* *range upstream in the rivers Danube, Dniester, Dnieper, Don, and Volga (Bogutskaya and Naseka 2002b, Cakić et al. 2002, Movchan 1988) as well as Lake Bafa in Turkey (Sarı et al. 1999).*

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0 √
Unknown	U

- *As a large (~15 cm) fish,* S. abaster *is not likely to adhere or be transported.*

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a) Is this species sold at aquarium/pet/garden stores ("brick & mortar" or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100
No, this species this species is rarely/never sold.	0 √
Unknown	U

- *An online search for this species did not yield any for sale.*

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0 √
Unknown	U

- *There is no indication that* S. abaster *occurs naturally in North America or that there would be any interest stocking.*

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is <u>likely</u> to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces), this activity <u>may</u> occur within 20 km of the basin because of the species' popularity/value.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100
No, this species is not commercially cultured in or transported through the Great Lakes region.	0 √
Unknown	U

- *There is no record either in the literature or online of* S. abaster *of being commercially cultured or transported.*

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100 √
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40
No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0
Unknown	U

- *Ballast water exchange is predicted to have a low effectiveness for this species, as it has high salinity tolerances (Snyder et al. 2014).*

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5 √
Yes, but this species has neither been observed in ballast/fouling ships entering the Great Lakes nor in ports in direct trade with the Great Lakes.	Score x 0.1
No, this species does not occur in waters from which shipping traffic to the Great Lakes	Score x 0

originates.	
Unknown	U

- *The original* S. abaster *distribution area includes coastal habitats and the lower reaches of rivers of the Caspian, Azov, Black, and Mediterranean Sea basins, as well as the Atlantic coast from Gibraltar to the southern Bay of Biscay (Kottelat and Freyhof 2007). During the 20th century, this fish species expanded its range upstream in the rivers Danube, Dniester, Dnieper, Don, and Volga (Bogutskaya and Naseka 2002a and 2002b, Cakić et al. 2002, Movchan 1988) as well as Lake Bafa in Turkey (Sarı et al. 1999).*

Vector Potential Scorecard					
Vector		**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind		**0**	x	**0**	Unlikely
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.		**0**	x	**0**	Unlikely
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)		**0**	x	**0**	Unlikely
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)		**0**	x	**0**	Unlikely
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)		**0**	x	**0**	Unlikely
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling		**100**	x 0.5	**50**	Moderate
Total Unknowns (U)	**0**	**Confidence Level**		High	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

ESTABLISHMENT POTENTIAL RESULTS

Status: **Not established in North America, including the Great Lakes**

***Syngnathus abaster* has a moderate probability of establishment if introduced to the Great Lakes (Confidence level: High).**

The Great Lakes include a large amount of the preferred habitat for *Syngnathus abaster* (muddy vegetated bottoms with slow current). The wide distribution of this species in heavily-disturbed rivers of Europe indicates it would tolerate pollution and other disturbances, which are found in various parts of the Great Lakes.

Syngnathus abaster prefer harpaciticoids of the genus Tisbe; several harpacticoid copepods from Eurasia have been introduced into the Great Lakes. In addition to this, there are no reported enemies in either its native or introduced range; however, it is a slow-moving species so it may be vulnerable to predation by larger fish, such as salmon and trout.

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
	7

- *This species is euryhaline and can survive in marine, fresh, and brackish water (Dawson 1986).*
- S. abaster *can survive in a wide range of temperature between 8° to 24°C (Dawson 1986), has been recorded in water from 4° to 5.5°C (Franzoi et al. 1993).*
- *This species lives among sand-, mud-, or seagrass beds between depths of 0.5m and 5 m (Dawson 1986), though muddy vegetated habitat with slow current preferred (Ondračková et al. 2012b).*
- *The Black-striped Pipefish has a high salinity tolerance (>28 ppt) across all life history stages (Snyder et al. 2014)*
- *This species has suceesfully established in freshwater habitats (Tutman et al. 2012)*

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9
Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
	8

- *This species survisies in a wide range of temperature between 8° to 24°C (Dawson 1986), has been recorded in water from 4° to 5.5°C (Franzoi et al. 1993)*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
	6

- *The most important food item for* S. abaster *are harpaciticoids of the genus Tisbe, though phytal amphipods and other phytal organisms also contribute to its diet (Franzoi et al. 1993).*

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	0
Unknown	U
	3

- *Where this species has spread in the River Danube, it represents 3.7% of all fish collected (Ondračková et al. 2012b).*
- *The species has invaded areas with high diversity of ichthyofauna (Lenhardt et al. 2011).*

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
	6

- *This species produces twice as many eggs as the congener* S. taenionotus *and has four broods per reproductive season as opposed to two (Franzoi et al. 1993).*

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
	5

- *Reproductive strategy by* S.abaster, *in which the males carry eggs and larvae in brood pouches, make it more likely the early life history stages of Balck-striped Pipefish can survive harsh environments (Snyder et al. 2014).*

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0

Unknown	U
	4

- *This species is found at range of latitudes, including the Dneiper River near Kiev, Ukraine, 50°N (Tutman et al. 2012), so will likely experience similar climatic conditions.*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	6

- *This species can survive a wide range of temperature between 8° to 24°C (Dawson 1986), has been recorded in water from 4° to 5.5°C (Franzoi et al. 1993).*
- *The Great Lakes include a large amount of the preferred habitat (muddy vegetated bottoms with slow current).*
- *The wide distribution of this species in heavily-disturbed rivers of Europe indicate it would tolerate pollution and other disturbances.*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0
Unknown	U
	6

- *This species can survive a wide range of temperature between 8° to 24°C (Dawson 1986), has been recorded in water from 4° to 5.5°C (Franzoi et al. 1993)*
- *This species lives among sand-, mud-, or seagrass beds between depths of 0.5 and 5 m (Dawson 1986), though muddy vegetated habitat with slow current preferred (Ondračková et al. 2012b)*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these	9

changes due to its wide environmental tolerances)	
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0
Unknown	U
	8

- *This species survives a wide range of temperature between 8° to 24°C (Dawson 1986), has been recorded in water from 4° to 5.5°C (Franzoi et al. 1993). As such, moderate water temperature increases are likely to benefit this species.*
- *As a euryhaline species, increased salinization may give it competitive superiority over freshwater-only species.*

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
	7

- *The most important food item for this species are harpaciticoids of the genus Tisbe, though phytal amphipods and other phytal organisms also contribute to its diet (Franzoi et al. 1993). There are over 34 harpaciticoids species in the Great Lakes area (Hudson et al. 1998).*

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare	3

in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	
Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Great Lakes and is not likely to be introduced	-80% total points (at end)
Unknown	U
	9

- *No information was found in required to requiring another species for a critical stage in its life cycle.*

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes)	6
Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0
Unknown	U
	2

- *Several harpacticoid copepods from Eurasia have been introduced into the Great Lakes (*Kitokra hibernica *and* N. incerta*).*

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the	-10% total

establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0
Unknown	U
	-10%

- *No enemies have been mentioned in the native or introduced range; however as a slow-moving species it may be vulnerable to predation by larger fish such as salmon and trout.*

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9
Frequent, moderate inocula	6
Frequent, small inocula OR infrequent, large inocula	3
Infrequent, small or moderate inocula	0
Unknown	U
	0

- *Average brood size ~100 eggs, so inocula would be small. This species is not extremely abundant so the frequency of ballast uptake is likely small.*

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
	6

- *During the 20th century, this fish species expanded its range upstream in the rivers Danube, Dniester, Dnieper, Don, and Volga (Bogutskaya and Naseka 2002, Cakić et al. 200, Movchan 19882).*

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
	8

- *This species is likely to have extensive natural spread, over 100s of kilometers (Lenhardt et al. 2011, Ondračková et al. 2012b).*

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing the establishment and spread of this species)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent the establishment and/or spread of this species	0
Unknown	U
	0

Establishment Potential Scorecard				
Points	**Probability for Establishment**	A. Total Points (pre-adjustment)		91
>100	High	**Adjustments**		
		B. Critical species	A*(1- 0%)	91
51-99	Moderate	C. Natural enemy	B*(1- 10%)	81.9
		Control measures	C*(1- 0%)	81.9
0-50	Low	**Potential for Establishment**		Moderate
# of questions answered as "unable to determine"	**Confidence Level**			
0-1	High	Total # of questions unknown		0
2-5	Moderate			
6-9	Low	Confidence Level		High
>9	Very low			

Section C: Potential for Impact

IMPACT POTENTIAL RESULTS

Environmental: Unknown

Socio-Economic: Low

Beneficial: Low

Current research on the potential for environmental impacts to result from *Syngnathus abaster* if introduced to the Great Lakes is inadequate to support proper assessment.

There is insufficient information available to determine whether Syngnathus abaster poses as threat to other species or water quality. There are no reports on how it affects or interacts with other species. It is unknown whether this species alters the physical components of the ecosystem.

There is little or no evidence to support that Syngnathus abaster has the potential for significant socio-economic impacts if introduced to the Great Lakes.

It has not been reported that *Syngnathus abster* poses a threat to human health or water quality. There is no evidence that this species negatively impacts infrastructure, economic sectors, recreational activities and associated tourism, or the aesthetic appeal of the area it inhabits.

There is little or no evidence to support that Syngnathus abaster has the potential for significant beneficial impacts if introduced to the Great Lakes.

It has not been reported that *Syngnathus abster* can be used for the control of other organisms or improving water quality. There is no evidence that this species is commercially, recreationally, or medically valuable. It does not have a significant positive ecological impact.

POTENTIAL ENVIRONMENTAL IMPACT

NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1 √
Not significantly	0
Unknown	U

- *Black-striped Pipefish have been predicted to have negative impacts due to proxies such as history of invasion, small egg diameters and low minimum temperatures (Snyder et al. 2014).*
- *There was very little mention of impact in the literature. It has been described as "without apparent impact" (Lenhardt et al. 2011)*
- *It has been found to carry 17 parasites in native range, though only one has been found in freshwater habitats where* S. abaster *has been introduced.*

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1
Not significantly	0
Unknown	U √

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in the food web)	6
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival,	1

fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	
Not significantly	0
Unknown	U √

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0
Unknown	U √

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1
Not significantly	0
Unknown	U √

E6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1
Not significantly	0
Unknown	U √

Environmental Impact Total	**1**
Total Unknowns (U)	**5**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	Low
1	0	Low
0	≥2	**Unknown**
1	≥1	**Unknown**

POTENTIAL SOCIO-ECONOMIC IMPACT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1
Not significantly	0 √
Unknown	U

- *There is no information on disease or parasite transmission by this species to humans.*

S2) Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1
Not significantly	0 √
Unknown	U

S3) Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6

Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0 √
Unknown	U

S4) Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

Socio-Economic Impact Total	**0**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate

0	0-1	**Low**
1	0	
0	≥2	Unknown
1	≥1	

POTENTIAL BENEFICIAL EFFECT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular effect. An "Unknown" response is appropriate if the potential for a particular effect might be inferred but has not been explicitly reported or if there is an unresolved debate about a particular effect.

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1
Not significantly	0 √
Unknown	U

B2) Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?

Yes, it is economically important to at least one of these industries	6
Yes, but its economic contribution is small	1
Not significantly	0 √
Unknown	U

- *Considered a 'discard' fish of no economic importance (Pranovi et al. 2013)*

B3) Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local communities and/or tourism	6
It is sometimes employed recreationally, but adds little value to local communities or tourism	1
Not significantly	0 √
Unknown	U

- *No information was found in regards to its recreational value*

B4) Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR It is potentially important to medicine or research and is currently being or scheduled to be studied	1
Not significantly	0 √
Unknown	U

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1
Not significantly	0 √
Unknown	U

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1
Not significantly	0 √
Unknown	U

Beneficial Effect Total	**0**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**Low**
1	0	
0	≥2	Unknown
1	≥1	

A.2 Bivalves

Scientific Name: *Limnoperna fortunei* Dunker, 1857

Common Name: Golden Mussel

Synonyms: *Limnoperna siamensis, Limnoperna lacustris*

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: Unlikely

Hitchhiking/fouling: Unlikely

Unauthorized intentional release: Unlikely

Stocking/planting/escape from recreational culture: Unlikely

Escape from commercial culture: Unlikely

Transoceanic shipping: Low

***Limnoperna fortunei* has a low probability of introduction to the Great Lakes (Confidence level: High).**

Potential pathway(s) of introduction: Transoceanic Shipping

Limnoperna fortunei has a high tolerance to fluctuating salinities; no significant mortality was observed in mussels exposed to a salinity cycle with abrupt salinity changes ranging 1–23% (mean 2.68%) over a month (Sylvester et al. 2013). This will affect probability of uptake (many ports located in estuarine environments with fluctuating salinity) and survival after ballast exchange (Sylvester et al. 2013). Though tolerance of larvae has not been specifically examined, larval survival is likely due to presence of colonies in saline regions (unlikely formed by drifting adults) (Sylvester et al. 2013). Though little to no ship traffic arrives to the Great Lakes from South American or Asian ports, the potential exists.

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100
No, this species does not occur near waters connected to the Great Lakes basin and/or is	0 √

not mobile or able to be transported by wind or water.	
Unknown	U

- *This species does not occur near waters connected to the Great Lakes basin.*

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0 √
Unknown	U

- *The Golden Mussel may have been introduced to Japan as contaminant of shipments of live Asian clams from China (Crosier and Molloy 2004, Ghabooli et al. 2013, Magara et al. 2001), but Asian clams are not known to be shipped to the Great Lakes region.*

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a) Is this species sold at aquarium/pet/garden stores ("brick & mortar" or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100

No, this species this species is rarely/never sold.	0 √
Unknown	U

- *The Golden Mussel is not sold or available for purchase in the Great Lakes basin.*

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0 √
Unknown	U

- *The Golden Mussel is not stocked or planted in the Great Lakes basin.*

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is likely to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces), this activity may occur within 20 km of the basin because of the species' popularity/value.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100

No, this species is not commercially cultured in or transported through the Great Lakes region.	0 √
Unknown	U

- *There is no commercial culture of transport of Golden Mussel in the Great Lakes region.*

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80 √
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40
No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0
Unknown	U

- Limnoperna fortunei *has a high tolerance to fluctuating salinities; no significant mortality was observed in mussels exposed to a salinity cycle with abrupt salinity changes ranging 1–23 % (mean 2.68 %) over a month (Sylvester et al. 2013). Tolerance to this type of regime was unaffected by different temperatures within ambient ranges, and survival was 90% over 9 hours (Sylvester et al. 2013). In terms of the distance covered by a commercial vessel typically sailing at 13–24 knots (24–44 km/h), 9 h represents anywhere between 217 and 400 km, which in many areas exceeds the distance between the destination port and the site of mid-ocean exchange (Sylvester et al. 2013).*
- *This will affect probability of uptake (many ports located in estuarine environments with fluctuating salinity) and survival after ballast exchange (Sylvester et al. 2013). Though tolerance of larvae has not been specifically examined, larval survival is likely due to presence of colonies in saline regions (unlikely formed by drifting adults) (Sylvester et al. 2013).*

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5
Yes, but this species has neither been observed in ballast/fouling ships entering the Great Lakes nor in ports in direct trade with the Great Lakes.	Score x 0.1 √
No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0
Unknown	U

- *Though little to no ship traffic arrives to the Great Lakes from South American or Asian ports, the potential exists.*

Vector Potential Scorecard				
Vector	**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind	**0**	x	**0**	Unlikely
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.	**0**	x	**0**	Unlikely
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)	**0**	x	**0**	Unlikely
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)	**0**	x	**0**	Unlikely
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)	**0**	x	**0**	Unlikely
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling	**80**	x 0.1	**8**	Low
Total Unknowns (U)	**0**	**Confidence Level**	High	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High

40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

ESTABLISHMENT POTENTIAL RESULTS

Status: Not established in North America, including the Great Lakes

Limnoperna fortunei **has a high probability of establishment if introduced to the Great Lakes (Confidence level: High).**

Limnoperna fortunei can survive salinity shocks and changes allowing it transportation into the Great Lakes and the ability to acclimate to salinities around the Great Lakes. This species is already found in regions with climates similar to the Great Lakes and shows the ability to survive overwinter temperatures as low as 0°C. *L. fortunei* consumes a variety of phytoplankton and zooplankton making it able to adjust its diet based on prey availability in the Great Lakes if introduced.

The native and introduced ranges of *L. fortunei* include extremes of pollution, water temperature, pH, and nutrient levels, making it able to adapt to the many microhabitats throughout the Great Lakes. *Limnoperna fortunei* attaches well to hard substrate (including of biological origin), minimally to soft substrate, as well as macrophytes and reeds (Karatayev et al. 2007) and plastic bottles (Karatayev et al. 2010).

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
	8

- *The Golden Mussel can survive (90%) up to a salinity shock of 2 ppt for periods of at least 10 days (Angonesi et al. 2008).*

- *This species has a high tolerance to fluctuating salinities; no significant mortality was observed in Golden Mussels exposed to a salinity cycle with abrupt salinity changes ranging 1–23 ‰ (mean 2.68 ‰) over a month. Tolerance to this type of regime was unaffected by different temperatures within ambient ranges (Sylvester et al. 2013).*
- *Deaton et al. (1989) had 41% Golden Mussel survival in 800mOsm (seawater ~1000mOsm) water.*
- *Compared to* Dreissena polymorpha, Limnoperna fortunei *has higher resistance to anoxia, pollution (including eutrophication), pH, and high temperatures, longer reproduction periods and lower calcium requirements (3-4mg/L) (Karatayev et al. 2007). This broader tolerance indicates this species could have an even broader distribution in the Great Lakes than* D. polymorpha.

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9
Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
	7

- *This species overwinters in South Korea, with water temperature as low as 0°C (Oliveira et al. 2010). In Japan, minimum temperature in a reservoir with Golden Mussels was 4.2°C (Nakano et al. 2011)*
- *Experimental research supports the 5°C threshold for prolonged exposure (Oliveira et al. 2010)*
- *Based on broad thermal tolerances, Ricciardi (1998) predicts colonization into the lower North American Great Lakes.*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
	7

- L. fortunei *consumes a variety of phytoplankton and zooplankton (Frau et al. 2013, Rojas Molina 2012, Rojas Molina et al. 2010). Adults do well despite low food availability (Oliveira et al. 2010).*

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9

Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	0
Unknown	U
	8

- *This species negatively effects burrowing invertebrates and unionids (Karatayev et al. 2010) in South America, and may do the same in the Great Lakes given if in high densities. Such competitive exclusion is also seen in a similar species,* D. polymorpha.
- *This species may have outcompeted/overgrown the native gastropods in South America,* Chilina fluminae *and* Biomphalaria straminea*, as they became rare and eventually disappeared from study sites (Spaccesi and Capitulo 2012).*

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
	7

- *No data was found on natural* L. fortunei *fecundity, though very high rates of colonization suggest it is high (Karatayev et al. 2007).*
- *In the laboratory, it is similar to* D. polymorpha *(~11,000 eggs) (Cataldo and Boltovskoy, unpublished data in Karatayev et al. 2007).*
- L. fortunei *spawns continually, while* D. polymorpha *is a batch spawner, which may contribute to the former's success (Boltovskoy et al. 2006).*

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding	3

establishment in the Great Lakes based on these attributes)	
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
	3

- L. fortunei *spawns continually (Boltovskoy et al. 2006).*

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	6

- *While the climate in South America is quite mild, South Korea climate is similar to the Great Lakes. South Korea has a humid continental climate and a humid subtropical climate. Winters can be extremely cold with the minimum temperature dropping below −20 °C (−4 °F) in the inland region of the country: in Seoul, the average January temperature range is -7 to 1 °C (19 to 34 °F), and the average August temperature range is 22 to 30 °C (72 to 86 °F).*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	7

- *Levels of these abiotic factors are very similar between the Great Lakes and the native/introduced ranges. That is, like the Great Lakes, the native/introduced ranges include extremes of pollution, water temperature, pH and nutrient levels. Salinity is similar (or more extreme) in native/introduced habitats. Notably*, L. fortunei *inhabits heavily polluted areas, as well as water with low calcium (3-4mg/L).*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0
Unknown	U
	8

- L. fortunei *reproduction was triggered at 17°C in a study performed by Nakano et al. (2011).*
- *This species has a depth range of a few centimeters to 10m (Karatayev et al. 2010).*
- *This species attaches well to hard substrate (including of biological origin), minimally to soft substrate, as well as macrophytes and reeds (Karatayev et al. 2007) and plastic bottles (Karatayev et al. 2010).*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0
Unknown	U
	9

- *This species can withstand very warm temperatures, as well as low levels of salinization.*

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0

Unknown	U
	9

- *This species consumes a variety of phytoplankton and zooplankton (Frau et al. 2013, Rojas Molina 2012, Rojas Molina et al. 2010).. Adults do well despite low food availability (Oliveira et al. 2010).*

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Great Lakes and is not likely to be introduced	-80% total points (at end)
Unknown	U
	9

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes)	6
Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0

Unknown	U
	8

- *As* L. fortunei *can settle on biogenic substrate, the presence of dead shells from* D. polymorpha *and* D. bugensis *will likely facilitate establishment and spread by providing hard substrate.*

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0
Unknown	U
	0

- *While* L. fortunei *is preyed upon by fish, there is no evidence of prevention or mitigation of colonization in other areas (Molloy et al. 1997, Sylvester et al. 2005).*

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9
Frequent, moderate inocula	6
Frequent, small inocula OR infrequent, large inocula	3
Infrequent, small or moderate inocula	0
Unknown	U
	0

- *With little traffic from South America or Asia into the Great Lakes, the inoculation potential would be small.*

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
	6

- *This species was introduced into Hong Kong in 1965 and into Taiwan, Japan, and Argentina around 1990, in the latter case most probably through the Rio de la Plata estuary via ship's ballast water (Boltovskoy et al. 2009). It has since colonized practically the entire Rı´o de la Plata Catchment, including parts of Bolivia, Paraguay, Uruguay and Brazil (Paolucci et al. 2010).*

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
	7

- *This species was introduced into Argentina around 1990, and by the early 2000s* L. fortunei *had colonized practically all of the Rıo de la Plata watershed extending to Paraguay, Brazil, Uruguay, and Bolivia, and swiftly became the sole dominant organism on hard substrates (Boltovskoy et al. 2006).*

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing the establishment and spread of this species)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)

No control methods have been set to prevent the establishment and/or spread of this species	0
Unknown	U
	0

Establishment Potential Scorecard				
Points	**Probability for Establishment**	A. Total Points (pre-adjustment)		109
>100	High	**Adjustments**		
		B. Critical species	A*(1- 0%)	109
51-99	Moderate	C. Natural enemy	B*(1- 0%)	109
		Control measures	C*(1- 0%)	109
0-50	Low	**Potential for Establishment**		High
# of questions answered as “unable to determine”	**Confidence Level**			
0-1	High	Total # of questions unknown		0
2-5	Moderate			
6-9	Low	Confidence Level		High
>9	Very low			

Section C: Potential for Impact

IMPACT POTENTIAL RESULTS

Environmental: High

Socio-Economic: High

Beneficial: High

***Limnoperna fortunei* has the potential for high environmental impact if introduced to the Great Lakes.**

Limnoperna fortunei reach large densities (5000-250,000 individuals/m2 on hard substrate, and 90-2000 individuals/m2 on soft substrate (Frau et al. 2013); shifting productivity in the nutrient cycle from the pelagic zone to the benthic zone. This species filters water quickly clarifying water causing a reduction in primary production occurring within the water column. Nutrient concentrations and proportion are shifted to promote aggregation of solitary *Microcystis* spp. cells; this favors blooms of the noxious cyanobacteria (Cataldo et al. 2012a).

***Limnoperna fortunei* has the potential for high socio-economic impact if introduced to the Great Lakes.**

L. fortunei modifies nutrient concentrations and proportions, and promotes aggregation of solitary *Microcystis* spp. cells into colonies; both these effects can favor blooms of this often noxious cyanobacteria (Cataldo et al. 2012a). Gazulha et al. (2012) found that while single cells of cyanobacteria were accepted, filamentous and colonial cyanobacteria were rejected as pseudofeces, a preference that could enhance blooms.

Limnoperna fortunei can clog fouling water intake sieves and filters, pipes, heat exchangers, and condensers has become a common difficulty in industrial and power plants that use raw water, chiefly for cooling purposes (Boltovskoy et al. 2009, Cataldo et al. 2003, Goto 2002).

***Limnoperna fortunei* has the potential for high beneficial impact if introduced to the Great Lakes.**

Limnoperna fortunei has had similar impacts to *Dreissena polymorpha*, i.e., has led to a dramatic shift in the benthic trophic structure and a homogenization of freshwater communities, regardless of original substrate and community structure (Burlakova et al. 2012, Darrigran and Damborenea 2011, Sardiña et al. 2011). Also, this species has led to an increase in water transparency, a decrease in suspended matter, chlorophyll a, and primary production (Boltovskoy et al. 2009). The structure of functional feeding groups in the new community, including invasive bivalves, is overwhelmingly dominated by collectors-filterers (Burlakova et al. 2012).

Parallels with the *Dreissena polymorpha* highlight several important differences, including *Limnoperna fortunei's* higher resistance to anoxia, pollution, pH, and high temperatures, longer reproduction periods and lower calcium requirements (Karatayev et al. 2007), suggesting that, should *Limnoperna fortunei* reach North America or Europe, it will become an even more aggressive invader, especially in regions dominated by acidic, soft and contaminated waters (Boltovskoy et al. 2009).

POTENTIAL ENVIRONMENTAL IMPACT

NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6 √
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1
Not significantly	0
Unknown	U

- *In a mesocosm experiment, cell density, proportion of colonial cells and colony size of* Microcystis *spp. increased in all enclosures, but these increases were dramatically (and very significantly) higher in enclosures* *with 100 and, especially, with 300 Golden mussels, than in the controls. Enclosure density reflected realistic densities. The results indicated that* L. fortunei *modifies nutrient concentrations and proportions, and promotes aggregation of solitary* Microcystis *spp. cells into colonies; both these effects can favor blooms of this often noxious cyanobacteria (Cataldo et al. 2012a).*

- *Mechanisms through which this can occur may include: (i) modification of nutrient concentrations and the N : P ratio, (ii) selective grazing of solitary* Microcystis *spp. cells over colonial ones and (iii) production of chemical cues that trigger the formation of colonies (Boltovskoy et al. 2009).*
- *Gazulha et al. (2012) found that while single cells of cyanobacteria were accepted, filamentous and colonial cyanobacteria were rejected as pseudofeces, a preference that could enhance blooms.*
- L. fortunei *may also biomagnify contaminants, i.e., the pseudofeces that primarily consist of rejected contaminants are consumed by amphipods (Sardiña et al. 2011).*
- *This species has been found to attach to a native crab,* Trichodactylus borellianus*, which leads to higher energetic costs for locomotion and reduces ability to escape predators (Rojas Molina and Williner 2013).*
- *Another potential threat posed by this invader was reported by Ogawa et al. (2004). The authors identified widespread parasitic infections by bucephalid trematodes in several cyprinid fishes from the Uji river (Japan), suggesting that the infections started with the accidental introduction of infested first intermediate hosts (*Limnoperna fortunei*) (Ogawa et al. 2004).*

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6 √
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1
Not significantly	0
Unknown	U

- *This species may outcompete/overgrow the native South American gastropods,* Chilina fluminae *and* Biomphalaria straminea*, as they became rare and eventually disappeared from study sites (Spaccesi and Capitulo 2012).*
- *This species negatively effects burrowing invertebrates and unionids (Karatayev et al. 2010).*
- *This species negatively impacts zooplankton, and part of zooplankton decline may be due to starvation (i.e., mussel outcompetes zooplankton for food resources) (Rojas Molina 2012).*

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in the food web)	6 √
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	1
Not significantly	0
Unknown	U

- L. fortunei *has increased food availability in the benthic zone, which in part has increased invertebrate (excluding mussels) density 1.9 to 22 times and biomass 1.7 to 19 times (Burlakova et al. 2012).*

- *Karatayev et al. (2010) found a threefold increase in benthic invertebrate density and biomass.*
- *This species has homogenized benthic communities (Darrigran and Damborenea 2011, Sardiña et al. 2011); e.g., in one study 99.9% of community biomass consisted of the filtering collector trophic group (Burlakova et al. 2012)*
- L. fortunei *has shunted the dominant nutrient cycling from the pelagic to the benthic zone (Cataldo et al. 2012b, Darrigran and Damborenea 2011, Rojas Molina 2012).*
- *This species has been found to significantly reduced phytoplankton densities (>60%). Also, it has changed composition of the algae assemblages, most notably an increase in the flagellate group, relative to the diatom, single celled and colonial groups (Frau et al. 2013).*
- *Phytoplankton decreased 55-90% in mesocosm experiment with Gloden Mussel (Rojas Molina 2012).*
- *This species filters water substantially faster than* D. polymorpha *(Karatayev et al. 2010).*
- *This species consumes zooplankton:*
    - *Copepodites experienced 30% mortality in mussel treatments, compared to controls (Rojas Molina et al. 2013).*
    - *Gut content analysis found that microcrustaceans constitute about 67% of mussel diet biomass (Rojas Molina et al. 2010).*
    - *Significant declines in rotifers and cladocerans in mesocosm experiments with mussels*
- L. fortunei *can reach densities of 5000-250,000 ind/m2 on hard substrate, and 90-2000 ind/m2 on soft substrate (Frau et al. 2013).*

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0 √
Unknown	U

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6 √
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1
Not significantly	0
Unknown	U

- *An increase in water transparency, and a decrease in suspended matter, chlorophyll a, and primary production has been observed after Golden Mussel establishment (Boltovskoy et al. 2009).*
- *A decrease in turbidity and an increase in dissolved nitrogen has been found when Golden Mussels are present (Rojas Molina 2012).*

E6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6 √
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1
Not significantly	0
Unknown	U

- *Increased habitat complexity can lead to significant (e.g., threefold) increase in community taxonomic richness. Gloden Mussel shells increase surface area for settling organisms, and also provide refuges from predation and physical stressors (Burlakova et al. 2012, Darrigran et al. 1998, Darrigran and Damborenea 2011, Spaccesi and Capitulo 2012). This species transforms sand or mostly bare sediment into reef-like druses (Burlakova et al. 2012).*

Environmental Impact Total	**30**
Total Unknowns (U)	**0**

Scoring		
Score	# U	**Impact**
>5	Any	**<u>High</u>**
2-5	Any	Moderate
0	0-1	Low
1	0	
0	≥2	Unknown
1	≥1	

<u>POTENTIAL SOCIO-ECONOMIC IMPACT</u>

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1 √
Not significantly	0
Unknown	U

- *In a mesocosm experiment, cell density, proportion of colonial cells and colony size of* Microcystis *spp. increased in all enclosures, but these increases were dramatically (and very significantly) higher in enclosures with 100 and, especially, with 300 Golden Mussels, than in the controls. Enclosure density reflected realistic densities. The results indicate that* L. fortunei *modifies nutrient concentrations and proportions, and promotes aggregation of solitary* Microcystis *spp. cells into colonies; both these effects can favor blooms of this often noxious cyanobacteria (Cataldo et al. 2012a).*
- *Gazulha et al. (2012) found that while single cells of cyanobacteria were accepted, filamentous and colonial cyanobacteria were rejected as pseudofeces, a preference that could enhance blooms.*

S2) Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6 √
Yes, but the costs have been small and are largely reparable or preventable	1
Not significantly	0
Unknown	U

- L. fortunei *can clog or foul water intake sieves and filters, pipes, heat exchangers, and condensers has become a common difficulty in industrial and power plants that use raw water, chiefly for cooling purposes (Boltovskoy et al. 2009, Cataldo et al. 2003, Goto 2002,).*
- *Grit chambers and flocculators have been found heavily clogged with sediment of broken shell and tissue material (Crosier and Molloy 2004 , Goto 2002, Magara et al. 2001).*
- *This increases operational costs (complete shutdown of plant; clogging of mussels, shell material, and sediment may need to manually removed) (Crosier and Molloy 2004, Goto 2002).*

S3) Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1 √
Not significantly	0
Unknown	U

- *Decaying Golden Mussels pollute drinking water systems (Crosier and Molloy 2004).*

S4) Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and	6

tourism	
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6
Yes, but negative consequences have been small	1 √
Not significantly	0
Unknown	U

- *Decaying dead Golden Mussels emit a noxious odor (Crosier and Molloy 2004)*

Socio-Economic Impact Total	**9**
Total Unknowns (U)	**0**

Scoring		
Score	# U	**Impact**
>5	Any	**High**
2-5	Any	Moderate
0	0-1	Low
1	0	Low
0	≥2	Unknown
1	≥1	Unknown

POTENTIAL BENEFICIAL EFFECT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular effect. An "Unknown" response is appropriate if the potential for a particular effect might be inferred but has not been explicitly reported or if there is an unresolved debate about a particular effect.

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1

Not significantly	0 √
Unknown	U

B2) Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?

Yes, it is economically important to at least one of these industries	6
Yes, but its economic contribution is small	1
Not significantly	0 √
Unknown	U

B3) Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local communities and/or tourism	6
It is sometimes employed recreationally, but adds little value to local communities or tourism	1
Not significantly	0 √
Unknown	U

B4) Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR It is potentially important to medicine or research and is currently being or scheduled to be studied	1
Not significantly	0 √
Unknown	U

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1 √
Not significantly	0
Unknown	U

- *In experiments performed by Di Fiori et al. (2012) glyphosate decreased by 40% under large mussel presence, and was reduced by25% in empty shell treatments. The authors believe that part of the herbicide that disappeared from the water column was adsorbed in Golden Mussel valvae surface, while another was mineralized by microbial communities in shells' biofilm. Glyphosate is an herbicide with negative impacts on aquatic filtering organisms and sediment feeders. However, the Golden Mussel may speed up the bioavailability* *of the phosphorous in glyphosate, leading to eutrophication, but this is expected to be outweighed by the remediation of the herbicide (Di Fiori et al. 2012).*

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6 √
Yes, it provides some positive contribution to the ecosystem, but is not vital	1
Not significantly	0
Unknown	U

- *An increase in Golden Mmussel densities have been associated with a threefold increase in Argentina's freshwater fish landings in the Rio do la Plata basin after 1995, due to its status as a new, abundant food source (Boltovskoy et al. 2006). The Rio de la Plata system is otherwise poor in plankton (Boltovskoy et al. 2006).*
- *In a study of 15 fish taxa, 11 had veligers of* L. fortunei *in their gut (several of these fish species economically and environmentally important). Fish larvae with empty guts represented 60% (San Nicola´ s) to 72% (Parana´ River) of the total number of fish. Proportions of feeding fish larvae with* L. fortunei *veligers in their guts varied between 20% (San Nicola´ s) and 56% (Parana´ River); in 15% of the guts analyzed,* L. fortunei *was the only food item recorded. For those specimens that had consumed* L. fortunei *larvae and any other food item,* L. fortunei *was the most important item in 55% (Parana´ River) to 71% (San Nicola´ s) of the animals in terms of biomass. Consumption of* L. fortunei *veligers decreased as fish larvae grew and were able to capture more difficult prey (Paolucci et al. 2007).*
- *Feeding on veligers of* L. fortunei *significantly enhanced the growth of* P. lineatus *larvae and supported the idea that this new and abundant resource is selectively preyed upon by* P. lineatus *during its larval stage. Higher growth rates may have stemmed from the higher energy contents of veligers compared to crustaceans and/or from the lower energy costs of capturing slower prey (Paolucci et al. 2010).*
- *According to Boltovskoy et al. (2006), positive impacts of* L. fortunei *are not limited to fishes that directly consume Golden Mussels, but there are also indirect positive effects on ichthyophagous and detritivorous fish species. Fish larvae, e.g.* Salminus maxillosus, Rhaphiodon vulpinus, Pseudoplatystoma coruscans*,* Pseudoplatystoma fasciatum*, and metalarvae of other* Pimelodidae *that prey on other larval fish probably benefit from the mussel-enhanced growth rates of their prey.*

Beneficial Effect Total	**7**
Total Unknowns (U)	**0**

Scoring		
Score	# U	**Impact**
>5	Any	**<u>High</u>**
2-5	Any	Moderate
0	0-1	Low
1	0	Low
0	≥2	Unknown
1	≥1	Unknown

Scientific Name: *Monodacna colorata* Eichwald, 1829

Common Name: Colored Lagoon Cockle

Synonyms: *Monodacna colorata*

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: Unlikely

Hitchhiking/fouling: Unlikely

Unauthorized intentional release: Unlikely

Stocking/planting/escape from recreational culture: Unlikely

Escape from commercial culture: Unlikely

Transoceanic shipping: Moderate

***Monodacna colorata* has a moderate probability of introduction to the Great Lakes (Confidence level: High).**

Potential pathway(s) of introduction: Transoceanic Shipping (NOBOB vessels)

The introduction and spread of *Monodacna colorata* to non-native locations throughout Europe was facilitated by direct involvement from human vectors, likely including shipping (Grigorovich et al. 2003). Grigorovich et al. (2003) classify this species as a potential Great Lakes invader through ballast-mediated (NOBOB) introduction from ships originating in the Black-Azov Sea basin, though with reduced invasion likelihood due to ballast exchange or flushing. Specimens from the Caspian Sea are known to tolerate salinities up to 10 ppt (Karpevich 1960), while those from the Azov Sea quickly perish with salinities greater than 5 ppt (Zenkevich 1963). These physiological restrictions are expected to reduce the probability of introduction under current ballast water regulations (30 ppt flushing).

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100
No, this species does not occur near waters connected to the Great Lakes basin and/or is not mobile or able to be transported by wind or water.	0 √
Unknown	U

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0 √
Unknown	U

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a) Is this species sold at aquarium/pet/garden stores (“brick & mortar” or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100
No, this species this species is rarely/never sold.	0 √
Unknown	U

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0 √
Unknown	U

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is likely to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces), this activity may occur within 20 km of the basin because of the species' popularity/value.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100
No, this species is not commercially cultured in or transported through the Great Lakes region.	0 √
Unknown	U

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1

This activity is unregulated or minimally regulated and is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80 √
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40
No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0
Unknown	U

- *Grigorovich et al. (2003) classify this species as a potential Great Lakes invader through ballast-mediated (NOBOB) introduction, though with reduced invasion likelihood due to ballast exchange or flushing.*
- *The introduction of this species to non-native locations in Europe was facilitated by direct involvement from human vectors, likely including shipping (Grigorovich et al. 2003).*
- *Specimens from the Caspian Sea are known to tolerate salinities up to 10 ppt (Karpevich 1960), while those from the Azov Sea quickly perish with salinities greater than 5 ppt (Zenkevich 1963). These physiological restrictions are expected to reduce the probability of introduction under current ballast water regulations (30 ppt flushing).*

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5 √
Yes, but this species has neither been observed in ballast/fouling ships entering the Great Lakes nor in ports in direct trade with the Great Lakes.	Score x 0.1
No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0
Unknown	U

- Monodacna colorata *is likely to be introduced by ships originating in the Black-Azov Sea basin (Grigorovich et al. 2003).*

Vector Potential Scorecard				
Vector	**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind	**0**	x	**0**	Unlikely
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.	**0**	x	**0**	Unlikely
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)	**0**	x	**0**	Unlikely
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)	**0**	x	**0**	Unlikely
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)	**0**	x	**0**	Unlikely
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling	**80**	x 0.5	**40**	Moderate
Total Unknowns (U) **0**		**Confidence Level**	High	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

ESTABLISHMENT POTENTIAL RESULTS

Status: Not established in North America, including the Great Lakes

***Monodacna colorata* has a moderate probability of establishment if introduced to the Great Lakes (Confidence level: Moderate).**

Specimens from the Caspian Sea are known to tolerate salinities of 1-10 ppt (Karpevich 1960), while those from the Azov quickly perish in salinities greater than 5 ppt (Zenkevich 1963). This is well within the range of the Great Lakes; however, Shokhin et al. (2006) reported that juveniles best develop at a salinity of 5 ppt. This is higher than the typical range within the Great Lakes and may be a physiological factor that restricts establishment. Establishment may be further restricted by the inability of juveniles to overwinter; when shallow water regions become chilled, sexually immature individuals die out. Older (2-3 year old) individuals have adapted behaviorally to avoid these conditions by migrating to deeper waters of 4-5 m (Shokhin et al. 2006), but populations are still negatively affected. In 2003, severe winter conditions caused average biomass densities of *M. colorata* in areas of the Azov Sea to drop to 3.2 g/m^2, down from usual densities of up to 600 g/m^2 (Shokhin et al. 2006).

Monodacna colorata requires a sandy bottom environment with high oxygen content (Shokhin et al. 2006) and is reported to co-occur with the invasive *Dreissena polymorpha* in substrate at depths of 20-50 m (Kosova 1963). This habitat type is readily abundant in the Great Lakes, with possibly the exception of Lake Erie's periodic anoxic conditions (Summers 2001). It feeds upon planktonic green algae, diatoms, and detritus (Zaitsev and Öztürk 2001), none of which are limiting within the Great Lakes. *Monodacna colorata* is likely to benefit from the predicted effects of climate change, including reduced ice-cover duration and warmer temperatures. This is evidenced by the massive reduction in biomass density in areas of the Azov Sea following harsh winter conditions in 2003 (Shokhin et al. 2006). Increased salinization, as predicted in the Great Lakes (Rahel and Olden 2008) is also likely to benefit this species, as juveniles best develop in salinity of 5 ppt and adults best dwell and reproduce in 8-9 ppt (Shokhin et al. 2006). This effect may also benefit *M.. colorata* is terms of reduced competition with native bivalves (more than 40 species) that may be intolerant of salinity increases.

There are no reported occurrences of *M. colorata* outcompeting another species within its native or introduced ranges throughout Europe. This species shows relatively low biomass densities in comparison to other species within benthic communities of Taganrog Bay in the Azov Sea (Shokhin et al. 2006) after once being reported as the dominant species there (Karatayev et al. 1997, Nekrasova 1971, Vorobiev 1949). In recent years, it has experienced native population reductions in areas of the Black Sea and is under strict protection in Romania (Popa et al. 2011).

Monodacna colorata is preyed upon by bottom dwelling fish (Zaitsev and Öztürk 2001); however, the extent to which this predation will prevent the establishment of populations in the Great Lakes is unknown. It was intentionally stocked into the Veselovsky Reservoir, Russia from 1951-1956 for the purpose of enhancing fish diet (Grigorovich et al. 2003, Kruglova 1961, Zhuravel 1969, Zhuravel 1975). From there, it spread relatively quickly to other canals and reservoirs and reached the Caspian Sea and Volga delta—probably as a result of shipping traffic with the opening of the Volga-Don Canal (Grigorovich et al. 2003). Within 7 years of the opening of the canal in 1952, this species had spread from the Black-Azov Sea basin into the Caspian Sea (Saenkova 1956). In 1960, one year after appearing in the Caspian, this species was observed in the lower Volga River (Kosova 1963). Panov et al. (2009) classify this species as having a high probability of dispersal as well as a high probability of establishment once introduced to a new inland waterway based on information from Son (2007).

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
	4

- *Specimens of this species from the Caspian Sea are known to tolerate salinities of 1-10 ppt (Karpevich 1960), while those from the Azov quickly perish in salinities greater than 5 ppt (Zenkevich 1963).*
- Monodacna colorata *inhabits areas of shallow sand and sand-aleuritic benthic deposits with high oxygen content (Nabozhenko and Kovalenko 2011).*
- *The physiological tolerance of this species to other parameters is unreported.*

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9
Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
	5

- *When shallow water regions become chilled, sexually immature individuals of this species die out; while 2-3 year old individuals have adapted behaviorally to avoid these conditions by migrating to deeper waters of 4-5 m (Shokhin et al. 2006).*
- *In 2003, severe winter conditions caused average biomass densities of* M. colorata *in areas of the Azov to drop to 3.2 g/m^2, down from usual densities of up to 600 g/m^2 (Shokhin et al. 2006).*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3

This species is an autotroph.	0
Unknown	U
	9

- *This species filter feeds on planktonic green algae, diatoms, and detritus (Zaitsev and Öztürk 2001).*

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	0
Unknown	U
	3

- *There are no reported occurrences of* M. colorata *outcompeting another species within its native or introduced ranges throughout Europe. This species shows relatively low biomass densities in comparison to other species within benthic communities of Taganrog Bay in the Azov Sea (Shokhin et al. 2006) after once being reported as the dominant species there (Karatayev et al. 1997).*
- *This species shows relatively low biomass densities in comparison to other species within benthic communities of Taganrog Bay in the Azov Sea (Shokhin et al. 2006).*
- *In recent years, it has experienced native population reductions in areas of the Black Sea and is under strict protection in Romania (Popa et al. 2011).*

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
	6

- *The fecundity of the related* Monodacna angusticostata *may reach several hundred thousand eggs (Malinovskaya 1961).*

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
	U

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- *This species originates in the Black and Azov Seas where climatic conditions are very similar to those of the Great Lakes.*
- *The Great Lakes and Ponto-Caspian region are "climatically compatible," which is one of the attributing factors to the success of Ponto-Caspian species in the Great Lakes (Reid and Orlova 2002).*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	3

- *The reported salinity ranges tolerated by* M. colorata *(<10 ppt (Karpevich 1960), <5 ppt (Zenkevich 1963)) are well within Great Lakes ranges.*
- *Shokhin et al. (2006) reported that juveniles best develop at a salinity of 5 ppt, which is higher than the typical salinity range in the Great Lakes.*
- *Abiotic factors and climatic conditions of the native range is quite similar to the Great Lakes, making the region compatible (Grigorovich et al. 2003, Reid and Orlova 2002).*
- *Great Lakes underwent similar anthropogenic eutrophication as the Ponto-Caspian region (Reid and Orlova 2002). Surface water temperature is similar between the Great Lakes and Ponto-Caspian seas (Grigorovich et al. 2003, Reid and Orlova 2002, USEPA 2008).*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0
Unknown	U
	8

- Monodacna colorata *requires a sandy bottom environment with high oxygen content (Shokhin et al. 2006) and is reported to co-occur with the Great Lakes invasive* Dreissena polymorpha *in substrate at depths of 20-50 m (Kosova 1963). This habitat type is readily abundant in the Great Lakes, with possibly the exception of Lake Erie's periodic anoxic conditions (Summers 2001).*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0
Unknown	U
	9

- Monodacna colorata *is likely to benefit from the predicted effects of climate change, including reduced ice-cover duration and warmer temperatures. This is evidenced by the massive reduction in biomass density in areas of the Azov Sea following harsh winter conditions in 2003 (Shokhin et al. 2006). Increased salinization as predicted in the Great Lakes (Rahel and Olden 2008) is also likely to benefit this species, as Shokhin et al. (2006) report that it best develops in salinity of 5 ppt and adults best dwell and reproduce in 8-9 ppt. This effect may also benefit* M. colorata *is terms of reduced competition with native bivalves (more than 40 species) that may be intolerant of salinity increases.*

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
	9

- Monodacna colorata *filter feeds on planktonic green algae, diatoms, and detritus (Zaitsev and Öztürk 2001), none of which are limiting within the Great Lakes.*

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Great Lakes and is not likely to be introduced	-80% total points (at end)
Unknown	U
	9

- *There is no critical species required by* M. colorata.

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes)	6
Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0
Unknown	U
	0

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0
Unknown	U
	U

- Monodacna colorata *is preyed upon by bottom dwelling fish (Zaitsev and Öztürk 2001); however, the extent to which this predation will prevent the establishment of populations in the Great Lakes is unknown.*

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9
Frequent, moderate inocula	6

Frequent, small inocula OR infrequent, large inocula	3
Infrequent, small or moderate inocula	0
Unknown	U
	U

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
	6

- Monodacna colorata *was intentionally stocked into the Veselovsky Reservoir, Russia from 1951-1956 for the purpose of enhancing fish diet (Grigorovich et al. 2003, Kruglova 1961, Zhuravel 1969, Zhuravel 1975). From there, it spread to other canals and reservoirs and reached the Caspian Sea and Volga delta—likely as a result of shipping traffic with the opening of the Volga-Don canal (Grigorovich et al. 2003).*
- *Panov et al. (2009) classify this species as having a high probability of dispersal as well as a high probability of establishment once introduced to a new inland waterway based on information from Son (2007).*

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
	7

- *Within 7 years of the opening of the Volga-Don canal in 1952, this species had spread from the Black-Azov Sea basin into the Caspian (Saenkova 1956).*
- *In 1960, one year after appearing in the Caspian Sea, this species was observed in the lower Volga River (Kosova 1963).*

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing the establishment and spread of this species)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent the establishment and/or spread of this species	0
Unknown	U
	0

<table>
<tr><th colspan="5">Establishment Potential Scorecard</th></tr>
<tr><td>Points</td><td>Probability for Establishment</td><td colspan="2">A. Total Points (pre-adjustment)</td><td>86</td></tr>
<tr><td rowspan="2">>100</td><td rowspan="2">High</td><td colspan="2">Adjustments</td><td></td></tr>
<tr><td>B. Critical species</td><td>A*(1- 0%)</td><td>86</td></tr>
<tr><td rowspan="2">51-99</td><td rowspan="2">Moderate</td><td>C. Natural enemy</td><td>B*(1- 0%)</td><td>86</td></tr>
<tr><td>Control measures</td><td>C*(1- 0%)</td><td>86</td></tr>
<tr><td>0-50</td><td>Low</td><td colspan="2">Potential for Establishment</td><td>Moderate</td></tr>
<tr><td># of questions answered as “unable to determine”</td><td>Confidence Level</td><td colspan="3"></td></tr>
<tr><td>0-1</td><td>High</td><td colspan="2" rowspan="2">Total # of questions unknown</td><td rowspan="2">3</td></tr>
<tr><td>2-5</td><td>Moderate</td></tr>
<tr><td>6-9</td><td>Low</td><td colspan="2" rowspan="2">Confidence Level</td><td rowspan="2">Moderate</td></tr>
<tr><td>>9</td><td>Very low</td></tr>
</table>

Section C: Potential for Impact

IMPACT POTENTIAL RESULTS

Environmental: Unknown

Socio-Economic: Low

Beneficial: Low

Current research on the potential for environmental impacts to result from *Monodacna colorata* if introduced to the Great Lakes is inadequate to support proper assessment.

There are no reported cases of *M. colorata* outcompeting other species within its native or introduced ranges throughout Europe, though at one time it was the dominant species over *D. polymorpha* in Taganrog Bay of the Azov Sea (Karatayev et al. 1997, Nekrasova 1971, Vorobiev 1949). Any negative effects on water quality or substrate composition caused by filter feeding (Zaitsev and Öztürk 2001) and its inhabitance of high-oxygen sandy benthic communities (Shokhin et al. 2006) are unreported.

There is little or no evidence to support that *Monodacna colorata* has the potential for significant socio-economic impacts if introduced to the Great Lakes.

Panov et al. (2009) classify *M. colorata* as a white-list species, able to readily disperse and establish but not at high risk for causing significant socio-economic impacts.

There is little or no evidence to support that *Monodacna colorata* has the potential for significant beneficial effects if introduced to the Great Lakes.

Monodacna invalida was intentionally stocked into the Veselovsky Reservoir from 1951-1956 for the purpose of enhancing fish diet (Grigorovich et al. 2003, Kruglova 1961, Zhuravel 1969, Zhuravel 1975), though substantial increases in fishery production since its introduction have not been reported. This species is also listed as being edible to humans (Bourquin 2002).

POTENTIAL ENVIRONMENTAL IMPACT

NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1
Not significantly	0 √
Unknown	U

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified	6

spawning behavior) on one or more native populations	
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1
Not significantly	0 √
Unknown	U

- *There are no reported cases of* M. colorata *outcompeting another species within its native or introduced ranges throughout Europe.*

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in the food web)	6
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	1
Not significantly	0 √
Unknown	U

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0 √
Unknown	U

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1
Not significantly	0
Unknown	U √

- Monodacna colorata *filter feeds on green planktonic algae, diatoms, and detritus (Zaitsev and Öztürk 2001), though any resulting effects on water quality are unreported.*

E6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1
Not significantly	0
Unknown	U √

- *This species inhabits sandy bottom environments with high oxygen content (Shokhin et al. 2006), though any physical effect it may have on the benthic ecosystem is unreported.*

Environmental Impact Total	**0**
Total Unknowns (U)	**2**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	Low
1	0	
0	≥2	**Unknown**
1	≥1	

POTENTIAL SOCIO-ECONOMIC IMPACT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1
Not significantly	0 √

Unknown	U

S2) Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1
Not significantly	0 √
Unknown	U

S3) Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0 √
Unknown	U

S4) Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6
Yes, but negative consequences have been small	1
Not significantly	0 √

Unknown	U

Socio-Economic Impact Total	**0**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**Low**
1	0	
0	≥2	Unknown
1	≥1	

POTENTIAL BENEFICIAL EFFECT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular effect. An "Unknown" response is appropriate if the potential for a particular effect might be inferred but has not been explicitly reported or if there is an unresolved debate about a particular effect.

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1
Not significantly	0 √
Unknown	U

B2) Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?

Yes, it is economically important to at least one of these industries	6
Yes, but its economic contribution is small	1 √
Not significantly	0
Unknown	U

- Monodacna invalida *was intentionally stocked into the Veselovsky Reservoir from 1951-1956 for the purpose of enhancing fish diet (Grigorovich et al. 2003, Kruglova 1961, Zhuravel 1969, Zhuravel 1975), though substantial increases in fishery production since its introduction have not been reported.*
- *This species is also listed as being edible by humans (Bourquin 2002).*

B3) Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local communities and/or tourism	6
It is sometimes employed recreationally, but adds little value to local communities or tourism	1
Not significantly	0 √
Unknown	U

B4) Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR It is potentially important to medicine or research and is currently being or scheduled to be studied	1
Not significantly	0 √
Unknown	U

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1
Not significantly	0 √
Unknown	U

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1
Not significantly	0 √
Unknown	U

Beneficial Effect Total	**1**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**Low**
1	0	
0	≥2	Unknown
1	≥1	

A.3 Bryozoans

Scientific Name: *Fredericella sultana*
Blumenbach, 1779

Common Name: Branching Bryozoan, Moss Animal

Synonyms:

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: Unlikely

Hitchhiking/fouling: Low

Unauthorized intentional release: Unlikely

Stocking/planting/escape from recreational culture: Unlikely

Escape from commercial culture: Unlikely

Transoceanic shipping: High

***Fredericella sultana* has a high probability of introduction to the Great Lakes (Confidence level: High).**

Potential pathway(s) of introduction: Transoceanic Shipping, Hitchhiking/Fouling

The production of resting stage statoblasts provide *F. sultana* with resistance to a variety of chemical and physical stressors, including extreme temperatures, periods of drought, and a variety of chemical treatments (Kipp et al. 2010, Wood 2005a). Statoblasts will generally remain viable after being exposed to a 1-2 ppt medium for up to two years and will quickly germinate upon return to freshwater (Kipp et al. 2010, Wood 2005b). The properties and hardiness exhibited by these statoblasts make this species a prime candidate to be taken up and transported in the ballast water of transoceanic ships (Bailey et al. 2005a, Kipp et al. 2010). In a survey of 33 randomly chosen ships with NOBOB tanks visiting the Great Lakes between December 2000 and December 2002, 3 ships (9.1%) possessed statoblasts of *F. sultana* within their ballast sediment (Kipp et al. 2010). This species made up only 0.7% of total bryozoan statoblast abundance (n=409) within the ships surveyed, for a total of 3 individuals. Statoblasts produced by this organism are also known to thrive in slightly brackish water, increasing the likelihood of transport via ballast tanks (Bailey et al. 2005a, Everitt 1975, Kipp et al. 2010, Massard and Geimer 2008). It is estimated that in ships with NOBOB tanks, up to one million statoblasts may be transported in a single voyage (Kipp et al. 2010).

As *F. sultana* lacks buoyant statoblasts, individuals are likely to be distributed by drifting fragments of colonies or by substrata such as aquatic plants and other dormant structures (Wood 2005). However, this species has not been observed in any waterways directly connected to the Great Lakes basin, thus diminishing the threat of introduction by dispersal and/or fouling. Bryozoan species have been known to exhibit distributions following those of bird migration routes (Wood 2002), and wastewater treatment plants noticing bryozoans present in their secondary water clarifiers tend to note frequent visits by ducks, possibly transporting viable statoblasts from their natural habitats (Wood 2005).

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100
No, this species does not occur near waters connected to the Great Lakes basin and/or is not mobile or able to be transported by wind or water.	0 √
Unknown	U

- *While* F. sultana *lacks buoyant statoblasts, it is likely to be distributed by drifting colony fragments or by substrata such as aquatic plants or other dormant structures (Wood 2005).*
- *This species has not been observed in any waterways directly connected to the Great Lakes basin, thus diminishing the threat of introduction by dispersal.*

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100 √
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0
Unknown	U

- *Bryozoan species have been known to exhibit distributions following those of bird migration routes (Wood 2002), and wastewater treatment plants noticing bryozoans present in their secondary water clarifiers tend to* *note frequent visits by ducks, possibly transporting viable statoblasts from their natural habitats (Wood 2005). Substrata, such as drifting aquatic plants and other non-living materials are thought to be likely transport mechanisms for this species.*

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1 √
Unknown	U

- *As a cosmopolitan species,* F. sultana *may be present in North America, but specimens previously thought to be this species have alternatively been proposed to be* F. indica *(Wood and Backus 1992).*

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a) Is this species sold at aquarium/pet/garden stores (“brick & mortar” or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100
No, this species this species is rarely/never sold.	0 √
Unknown	U

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0 √
Unknown	U

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is <u>likely</u> to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces), this activity <u>may</u> occur within 20 km of the basin because of the species' popularity/value.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100
No, this species is not commercially cultured in or transported through the Great Lakes region.	0 √
Unknown	U

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100 √
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40
No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0
Unknown	U

- *The production of resting stage statoblasts provides* F. sultana *with resistance to a variety of chemical and physical stressors, including extreme temperatures, periods of drought, and a variety of chemical treatments (Kipp et al. 2010, Wood 2005).*
- *Statoblasts will generally remain viable after being exposed to a 1-2 ppt medium for up to two years and will quickly germinate upon return to freshwater (Kipp et al. 2010, Wood 2005b).*
- *The hardiness exhibited by their statoblasts make this species a prime candidate to be taken up and transported in the ballast water of transoceanic ships (Bailey et al. 2005a, Kipp et al. 2010).*
- *Ballast flushing regulations are currently in place for the purpose of purging statoblasts at sea and reducing the number of retained statoblasts when exposed to open ocean seawater in tanks. Since these measures were implemented in 2006, there has been no apparent decline in statoblast occurrence or abundance among bryozoans as a group (Briski et al. 2010).*

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1 √
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5
Yes, but this species has neither been observed in ballast/fouling ships entering the Great Lakes nor in ports in direct trade with the Great Lakes.	Score x 0.1
No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0
Unknown	U

- *In a survey of 33 randomly chosen ships with NOBOB tanks visiting the Great Lakes between December 2000 and December 2002, 3 ships (9.1%) possessed statoblasts of* F. sultana *within their ballast sediment (Kipp et al. 2010). This species made up 0.7% of total bryozoan statoblast abundance (n=409) within the ships surveyed, for a total of 3 individuals (Kipp et al. 2010).*

Vector Potential Scorecard					
Vector		**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind		**0**	x	**0**	Unlikely
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.		**100**	x 0.1	**10**	Low
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)		**0**	x	**0**	Unlikely
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)		**0**	x	**0**	Unlikely
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)		**0**	x	**0**	Unlikely
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling		**100**	x 1	**100**	High
Total Unknowns (U)	**0**	**Confidence Level**		High	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

<u>ESTABLISHMENT POTENTIAL RESULTS</u>

Status: **Not established in North America, including the Great Lakes**

***Fredericella sultana* has a moderate probability of establishment if introduced to the Great Lakes (Confidence level: Moderate).**

Fredericella sultana is able to survive a broad range of physiological conditions from a resting stage statoblast through the adult phase. The production of highly resistant statoblasts as the primary reproductive mechanism in this species increase the likelihood of establishment to new areas, as they are tolerant of extreme temperatures, periods of drought, and exposure to organic pollution, heavy metals, toxins, pesticides, and herbicides (Kipp et al. 2010). It can persist in water temperatures ranging from 0°C in the resting stage to over 20°C as adult colonies (Tops et al. 2009). Colonies occur naturally at salinities of 0 ppt and are known to tolerate slightly brackish conditions of 3-4 ppt (Occhipinti Ambrogi and d'Hondt 1981). Increasing temperatures and elevated nutrient levels from increased runoff predicted by climate change are expected to increase the invasion success of this species. Greatest growth is achieved in high nutrient conditions (1 mg P/L and 10 mg N/L); however increased mortality occurs as nutrient levels decrease. At low nutrient levels (.06 mg P/L and 1 mg N/L), average colony mortality of 30% has been observed (Hartikainen et al. 2009). Additionally, Tops et al. (2009) observe a positive correlation between temperature and colony size, with colonies exposed to 20°C temperatures growing up to 160% of the size of colonies exposed to 14°C water. This prolific growth exhibited in high temperature and nutrient conditions makes *F. sultana* a great competitor for space. Colonies have been reported to reach biomass densities of up to 117 g/m^2 by the end of a growing season (Raddum and Johnsen 1983). Freeze resistant statoblasts have the ability to overwinter under ice and regenerate a new colony when conditions become favorable (Kipp et al. 2010, Thorp and Covich 2001, Wood 2005). Freezing and desiccation may be tolerated by these statoblasts for months to even years (Bushnell and Rao 1974).

Fredericella sultana is a filter feeding organism and diet preference is determined based upon prey availability throughout different seasons. Prey items are comprised primarily of flagellates, monads, cyanophyceans, and diatoms, none of which are expected to be a limiting resource for this species in the Great Lakes. The size of the mouth opening is the only limit to which particles can be consumed, with a maximum consumable particle size of about 240 micrometers (Raddum and Johnsen 1983). Multiplication by colonial fragmentation is an additional trait likely to increase invasion success. This species is considered cosmopolitan (Økland and Økland 2005), and likely exists or is able to exist in climatic conditions similar to those of the Great Lakes. *Fredericella sultana* is a common prey item for the Great Lakes native bluegill (*Lepomis macrochirus*), comprising over 75% of the diet of this fish at certain times of the year (Applegate 1966). However, the extent to which this predation will be effective in preventing the establishment of this species in the Great Lakes is unknown.

While no data exists for the spread of this particular species in non-native ranges, freshwater bryozoans with non-buoyant statoblasts are known to disperse rapidly through attachment to drifting substratum (such as plants and non-living objects), and through migrating waterfowl (Wood 2005). Ballast flushing regulations are currently in place for the purpose of purging statoblasts at sea and reducing the number of viable individuals entering the Great Lakes (see management). Ever since these measures were implemented in 2006, there has been no apparent decline in statoblast occurrence or abundance among bryozoans as a group in ballast sediment (Briski et al. 2010). However, no specific data is available on the effect of these regulations with regard to this particular species.

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide	9

ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
	6

- F. sultana *is able to survive a broad range of physiological conditions from a resting stage statoblast to the adult phase. It can survive in water temperatures ranging from 0°C as freeze resistant statoblasts to over 20°C as adult colonies (Tops et al. 2009). Colonies occur naturally at salinities of 0 ppt and are known to tolerate slightly brackish conditions of 3-4 ppt (Occhipinti Ambrogi and d'Hondt 1981).*
- *Greatest growth is achieved in high nutrient conditions (1 mg P/L and 10 mg N/L); however, increased mortality occurs as nutrient levels decrease. At low nutrient levels (.06 mg P/L and 1 mg N/L), average colony mortality of 30% has been observed (Hartikainen et al. 2009).*
- *Adult bryozoan colonies are usually unable to survive 3 hours of expose to anoxic conditions or water temperatures of 35°C or greater (Wood 2005a).*

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9
Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
	9

- *Freeze resistant statoblasts have the ability to overwinter under ice and regenerate a new colony when conditions become favorable (Kipp et al. 2010, Thorp and Covich 2001, Wood 2005). Freezing and desiccation may be tolerated by these statoblasts for months to even years (Bushnell and Rao 1974).*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
	6

- F. sultana *is a filter feeding organism, with diet preference determined by prey availability throughout different seasons. The size of the mouth opening is the only restriction on what particles can be consumed, with a maximum consumable size of 240 micrometers (Raddum and Johnsen 1983).*

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	0
Unknown	U
	6

- *This species exhibits prolific growth in high temperature and nutrient conditions (Hartikainen et al. 2009, Tops et al. 2009), making it a great competitor for space. Colonies have been reported to reach biomass densities of up to 117 g/m^2 by the end of a growing season (Raddum and Johnsen 1983).*

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
	U

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6

Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
	9

- *The production of highly resistant statoblasts as the primary reproductive mechanism in this species increases the likelihood of establishment to new areas, as they are tolerant of extreme temperatures, periods of drought, and exposure to organic pollution, heavy metals, toxins, pesticides, and herbicides (Kipp et al. 2010).*
- *Multiplication by fragmentation is an additional trait likely to increase invasion success.*

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	9

- *This species is considered cosmopolitan (Økland and Økland 2005), and likely exists or is able to exist in climatic conditions similar to those of the Great Lakes.*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	6

- F. sultana *is able to tolerate a wide range of water temperatures, ranging from 0°C as freeze resistant statoblasts and over 20°C as adult colonies (Tops et al. 2009). Colonies occur naturally at salinities of 0 ppt and are known to tolerate slightly brackish conditions of 3-4 ppt (Occhipinti Ambrogi and d'Hondt 1981).*
- *Greatest growth is achieved in high nutrient conditions (1 mg P/L and 10 mg N/L); however, increased mortality occurs as nutrient levels decrease (Hartikainen et al. 2009).*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0
Unknown	U
	9

- *This species has a broad global distribution, occurring in freshwater habitats throughout Europe, Asia, Australasia, and one location in western North America (Kipp et al. 2010, Wood 2002, Wood and Okamura 2005).*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0
Unknown	U
	6

- *Increasing temperatures and elevated nutrient levels from increased runoff are expected to increase the success of this species. Hartikainen et al. (2009) provides evidence for significantly increased growth rates with high nutrient concentrations (1 mg P/L and 10 mg N/L) and significantly greater mortality rates with low nutrient concentrations (.06 mg P/L and 1 mg N/L).*
- *Tops et al. (2009) observe a positive correlation between temperature and colony size, with colonies exposed to 20°C temperatures growing to 160% of the size of colonies exposed to 14°C.*

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9

Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
	9

- *The primary diet of* F. sultana *is comprised of flagellates, monads, cyanophyceans, and diatoms, none of which are expected to be a limiting resource for this species in the Great Lakes.*

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Great Lakes and is not likely to be introduced	-80% total points (at end)
Unknown	U
	9

- *There are no critical species required for survival by* F. sultana*.*

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established	6

and spread in the Great Lakes)	
Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0
Unknown	U
	0

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0
Unknown	U
	U

- F. sultana *is a common prey item for the Great Lakes native Bluegill (*Lepomis macrochirus*), comprising over 75% of the diet of this fish at certain times of the year (Applegate 1966). However, the effect of this predation on the establishment of this species is unknown.*

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9
Frequent, moderate inocula	6
Frequent, small inocula OR infrequent, large inocula	3
Infrequent, small or moderate inocula	0
Unknown	U

	0

- *In a survey of 33 vessels entering the Great Lakes over a two year period from 2000 to 2002, only 3 statoblasts of this species were collected in total, comprising just 0.7% of the total number of bryozoan statoblasts collected (Kipp et al. 2010).*

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
	0

- *There are no reported nonindigenous occurrences of this species.*

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
	U

- *While no data exist for the spread of this particular species in non-native ranges, freshwater bryozoans with non-buoyant statoblasts are known to disperse rapidly through attachment to drifting substratum (such as plants and non-living objects), and through migrating waterfowl (Wood 2005).*

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing the establishment and spread of this species)	-90% total points (at end)

Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent the establishment and/or spread of this species	0
Unknown	U
	0

Establishment Potential Scorecard				
Points	**Probability for Establishment**	A. Total Points (pre-adjustment)		84
>100	High	**Adjustments**		
		B. Critical species	A*(1- 0%)	84
51-99	Moderate	C. Natural enemy	B*(1- 0%)	84
		Control measures	C*(1- 0%)	84
0-50	Low	**Potential for Establishment**		Moderate
# of questions answered as "unable to determine"	**Confidence Level**			
0-1	High	Total # of questions unknown		3
2-5	Moderate			
6-9	Low	Confidence Level		Moderate
>9	Very low			

Section C: Potential for Impact

POTENTIAL IMPACT RESULTS

Environmental: High

Socio-Economic: High

Beneficial: Low

***Fredericella sultana* has the potential for high environmental impact if introduced to the Great Lakes.**

Once established, this species is likely to be a great competitor for space in areas of high nutrient concentration, able to reach biomass densities of up to 117 g/m^2 by the end of the growing season (Raddum and Johnsen 1983).

Fredericella sultana is the most common host of the myxozoan parasite *Tetracapsuloides bryosalmonae,* which causes proliferative kidney disease (PKD) in salmonid fish (Anderson et al. 1999, Feist et al. 2001, McGurk et al. 2005, McGurk et al. 2006, Morris and Adams 2006, Okamura and Wood 2002). PKD is a serious infection of both wild and farmed salmonids affecting mainly the kidney and spleen, and it can become systemic in many host fishes. It has been observed experimentally that native Rainbow Trout (*Oncorhynchus mykiss)* exposed for both short-term and long-term periods to bryozoans infected with *T. bryosalmonae* became infected with PKD as a result of the parasite (Feist et al. 2001). Recent research has indicted that widespread cases of PKD in Swiss rivers have caused over 25% mortality of the native wild Brown Trout populations (Borsuk et al. 2006, Wahli et al. 2002). Due to the capability of very few spores to cause infection in wild populations, mortality rates of individuals infected with PKD are able to reach 100% (Feist et al. 2001). PKD outbreaks are highly seasonal, typically occurring when water temperatures have reached 15°C (Hedrick et al. 1993). When water temperatures are below 10°C, PKD will not develop (Gay et al. 2001). In addition to disease development, higher temperatures seem to be associated with greater disease severity (Naich et al. 2003). Due to the strong effect of water temperature on the proliferation of PKD, climate change is likely to be a factor that will lead to an increase in the prevalence of this disease, especially in farmed fish populations (Tops et al. 2006). The clonal nature of *F. sultana* provides a highly suitable place for the cryptic stages of this parasite to settle, and it is presumed that multiplication of the parasite occurs in union with the multiplication of the bryozoan colony (Tops et al. 2004).

***Fredericella sultana* has the potential for high socioeconomic impact if introduced to the Great Lakes.**

Proliferative kidney disease has resulted in significant economic loss to both salmonid hatcheries and the rainbow trout fish farming industry (Anderson et al. 1999, Feist et al. 2001, Hedrick et al. 1993). While the effects of PKD on wild fish stocks tend to be poorly known (Feist et al. 2002, Hedrick et al. 1993), a recent study observed up to 25% mortality of a native brown trout population in a Swiss river containing the *T. bryosalmonae* parasite (Borsuk et al. 2006, Wahli et al. 2002).

It is also possible that this species could cause significant damage to infrastructure (e.g., water intake pipes). Bryozoans are one of the most common fouling animals and can impose serious economic costs by blocking conduits and end use devices. An extreme case of this occurred in Europe at the beginning of the century, when hundreds of tons *F. sultana* had to be removed from water pipelines throughout major cities (Harmer 1913). However, cases of such rapid colony production are extremely rare. The three major aspects of its life history that hinder biofouling control efforts are, first, the production of dormant statoblasts that can tolerate a wide range of physical and chemical conditions; second, the ability of bryozoan colonies to regenerate from pockets of living tissue; and third, its easy dispersal through air and water (Wood 2005a). Very few reliable experimental data are available on practical methods to control bryozoan fouling.

There is little or no evidence to support that *Fredericella sultana* has the potential for significant beneficial effects if introduced to the Great Lakes.

Due to the very poor digestion efficiency of *F. sultana*, this species must maintain a high turnover of nutrient particles. Therefore, colonies undergoing rapid growth may play an important role in nutrient cycling in a freshwater system as well as in determining phytoplankton dynamics (Raddum and Johnsen

1983). However, whether this will provide any ecologically significant beneficial impact in any part of the Great Lakes is unknown.

POTENTIAL ENVIRONMENTAL IMPACT

NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, and it has resulted in the reduction or extinction of one or more native species populations, affects multiple species, or is a reportable disease	6 √
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems, etc.)	1
Not significantly	0
Unknown	U

- *The freshwater bryozoan* Fredericella sultana *is the most common host of the myxozoan parasite* Tetracapsuloides bryosalmonae*, which causes proliferative kidney disease (PKD) in salmonoid fish (Anderson et al. 1999, Feist et al. 2001, Okamura and Wood 2002). PKD is a serious infection of both wild and farmed salmonids affecting mainly the kidney and spleen, and it can become systemic in many host fishes. It has been observed experimentally that native Rainbow Trout (*Oncorhynchus mykiss*) exposed to these bryozoans infected with* Tetracapsuloides bryosalmonae *for both short-term and long-term periods ended up becoming infected with PKD as a result of the parasite (Feist et al. 2001).*

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light, etc.)?

Yes, and it has resulted in significant adverse effects (e.g., critical reduction, extinction, behavioral changes, etc.) on one or more native species populations	6
Yes, and it has caused some noticeable stress to or decline of at least one native species population	1 √
Not significantly	0
Unknown	U

- *Once established, this species is likely to be a great competitor for space with other settling and colonizing organisms in areas of high nutrient concentration, able to reach extremely high biomass densities by the end of the growing season. This species is also able to remove nutrients from the water at rapid rates, potentially limiting their availability to plant species (Raddum and Johnsen 1983).*

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., added pressure to threatened/endangered species, significant reduction or extinction of any native species populations, creation of a dead end or any other significant alteration in the food web, etc.)	6

Yes, and it has resulted in some noticeable stress to or decline of at least one native species population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	1
Not significantly	0
Unknown	U √

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression, etc.)?

Yes, and it has caused a loss or alteration of genes which may be irreversible or has led to the decline or extinction of one or more native species	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0 √
Unknown	U

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles, etc.)?

Yes, and it has had a widespread, long term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been mild	1
Not significantly	0
Unknown	U √

E6) Does it alter the physical ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, changes to substrate (physical or chemical), etc.)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1 √
Not significantly	0
Unknown	U

- *Colonies undergoing rapid growth may play an important role in nutrient cycling in a freshwater system as well as in determining phytoplankton dynamics (Raddum and Johnsen 1983).*

Environmental Impact Total	**8**

Total Unknowns (U)	**2**

Scoring		
Score	# U	**Impact**
>5	Any	**<u>High</u>**
2-5	Any	Moderate
0	0-1	Low
1	0	
0	≥2	Unknown
1	≥1	

POTENTIAL SOCIO-ECONOMIC IMPACT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1
Not significantly	0 √
Unknown	U

S2) Does it cause damage to infrastructure (such as water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6 √
Yes, but the costs have been small and are largely reparable or preventable	1
Not significantly	0
Unknown	U

- *Bryozoans are probably the most common among fouling animals and can impose serious economic costs by blocking conduits and end use devices. An extreme case of this occurred in Europe at the beginning of the century, when hundreds of tons* F. sultana *had to be removed from water pipelines throughout major cities (Harmer 1913).*

S3) Does it negatively affect water quality?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6

Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0 √
Unknown	U

S4) Does it harm any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture, etc.)?

Yes, it has caused significant damage to one or more markets or economic sectors	6 √
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0
Unknown	U

- *Proliferative kidney disease has resulted in significant economic loss to both salmonid hatcheries and the rainbow trout fish farming industry (Anderson et al. 1999, Feist et al. 2001, Hedrick et al. 1993). While the effects of PKD on wild fish stocks tend to be poorly known (Feist et al. 2002, Hedrick et al. 1993), a recent study observed up to 25% mortality of a native Brown Trout population in a Swiss river containing the* Tetracapsuloides bryosalmonae *parasite (Borsuk et al. 2006, Wahli et al. 2002).*

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species, etc.)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

Socio-Economic Impact Total	**12**
Total Unknowns (U)	**0**

Scoring		
Score	# U	**Impact**

>5	Any	**High**
2-5	Any	Moderate
0	0-1	Low
1	0	
0	≥2	Unknown
1	≥1	

POTENTIAL BENEFICIAL EFFECT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular effect. An "Unknown" response is appropriate if the potential for a particular effect might be inferred but has not been explicitly reported or if there is an unresolved debate about a particular effect.

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1
Not significantly	0 √
Unknown	U

B2) Is it commercially valuable (e.g. for fisheries, aquaculture, agriculture, bait, ornamental trade, etc.)?

Yes, it is economically important to at least one of these industries	6
Yes, but its economic contribution is small	1
Not significantly	0 √
Unknown	U

B3) Is it recreationally valuable (e.g. for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local communities and/or tourism	6
It is sometimes employed recreationally, but adds little value to local communities or tourism	1
Not significantly	0 √
Unknown	U

B4) Does the species have some medicinal or research value (outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR It is potentially important to medicine or research and is currently being or scheduled to be studied	1
Not significantly	0 √
Unknown	U

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1
Not significantly	0
Unknown	U √

- *Due to the very poor digestion efficiency of* F. sultana*, this species must maintain a high turnover of nutrient particles. Therefore, colonies undergoing rapid growth may play an important role in nutrient cycling in a freshwater system as well as in determining phytoplankton dynamics (Raddum and Johnsen 1983). However, whether this will provide any ecologically significant beneficial impact in any part of the Great Lakes is unknown.*

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species which is threatened, endangered species, or commercially valuable, etc.)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1
Not significantly	0 √
Unknown	U

Beneficial Effect Total	**0**
Total Unknowns (U)	**1**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**<u>Low</u>**
1	0	

0	≥2	Unknown
1	≥1	

A.4 Crustaceans - Amphipods

Scientific Name: *Apocorophium lacustre*
Vanhoffen, 1911

Common Name: Scud

Synonyms:

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: Moderate

Hitchhiking/fouling: Moderate

Unauthorized intentional release: Unlikely

Stocking/planting/escape from recreational culture: Unlikely

Escape from commercial culture: Unlikely

Transoceanic shipping: Moderate

***Apocorophium lacustre* has a moderate probability of introduction to the Great Lakes (Confidence level: High).**

Potential pathway(s) of introduction: Dispersal, Hitchhiking/Fouling, Transoceanic Shipping

Apocorophium lacustre already occurs in waters connecting to the Great Lakes (Upper Mississippi River near Joliet, Illinois and the Ohio River (USGS 2013). *Apocorophium lacustre* could easily expand within the upper Mississippi River waterway via hull fouling associated with dreissenid mussel colonies (Grigorovich et al. 2008). *Apocorophium lacustre* is an abundant fouler (Llansó and Sillett 2009) and could easily be transported by recreational boaters and angerls from neighboring waters via fouling colonies. The strength of this recreational vector is unknown but is likely relatively infrequent and small. *Apocorophium lacustre* can be transported by ballast water (Power et al. 2006) and is able to survive large ranges of salinity (Wolf et al. 2009) making it capable of surviving to destinations within the Great Lakes.

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or	100 √

able to be transported by wind or water.	
No, this species does not occur near waters connected to the Great Lakes basin and/or is not mobile or able to be transported by wind or water.	0
Unknown	U

- Apocorophium lacustre *has been introduced into the Upper Mississippi River, Illinois River (near Joliet, Illinois), and Ohio River (USGS 2013) .*

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5 √
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25
Unknown	U

- *Joliet, Illinois is 72 km from Lake Michigan.*

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100 √
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0
Unknown	U

- Apocorophium lacustre *likely expanded within the Upper Mississippi River waterway via hull fouling, associated with dreissenid mussel colonies (Grigorovich et al. 2008).*
- Apocorophium lacustre *is an abundant fouler, accounting for 1-2% of total abundance on three vessels in Beaumont (Texas), and found in 18, 44 and 42% of samples. Cleaning of vessel with 42% frequency only reduced its frequency to 32% (Llansó and Sillett 2009).*
- *This species occurs in Florida waters (Camp et al. 1998), including the St. Johns River basin (Evans et al. 2004), which is the most significant river in Florida for recreational use.*
- *This species is present in Jacksonville (Florida), Wilmington (North Carolina), and Savannah (Georgia) (Power et al. 2006), as well as the Upper Mississippi River, Illinois River (near Joliet, Illinois), and Ohio River (USGS 2013).*

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5

	√
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1
Unknown	U

- *Joliet, Illinois is 72 km from Lake Michigan.*

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a) Is this species sold at aquarium/pet/garden stores ("brick & mortar" or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100
No, this species this species is rarely/never sold.	0 √
Unknown	U

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0 √
Unknown	U

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is likely to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5

This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces), this activity may occur within 20 km of the basin because of the species' popularity/value.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100
No, this species is not commercially cultured in or transported through the Great Lakes region.	0 √
Unknown	U

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100 √
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40
No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0

Unknown	U

- Apocorophium lacustre *is believed to be transported by ballast water (Power et al. 2006).*
- *It is euryhaline, surviving in salinities from 0-30 ppt (Wolf et al. 2009).*

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5 √
Yes, but this species has neither been observed in ballast/fouling ships entering the Great Lakes nor in ports in direct trade with the Great Lakes.	Score x 0.1
No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0
Unknown	U

- *This species occurs in the Rhine River and North Sea (Faasse and van Moorsel 2003).*
- *This species occurs in Florida waters (Camp et al. 1998), including the St. Johns River basin (Evans et al. 2004), which is the most significant river in Florida for commercial use.*
- Apocorophium lacustre *is native to the North American Atlantic coast from the Bay of Fundy, New Brunswick to the St. Johns River estuary, Florida (Bousfield 1973). It is regarded as introduced in the Gulf of Mexico and the southern North Sea coast of Europe (Bousfield 1973, Power et al. 2006, Grigorovich et al. 2008).*
- Apocorophium lacustre *was found in the Ohio River in 1996, and first detected in the Upper Mississippi River in 2005 (Grigorovich et al. 2008).*

Vector Potential Scorecard					
Vector		**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind		**100**	x 0.5	**50**	Moderate
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.		**100**	x 0.5	**50**	Moderate
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)		**0**	x	**0**	Unlikely
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)		**0**	x	**0**	Unlikely
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)		**0**	x	**0**	Unlikely
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling		**100**	x 0.5	**50**	Moderate
Total Unknowns (U)	**0**	**Confidence Level**		High	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

ESTABLISHMENT POTENTIAL RESULTS

Status: **Established in North America, but not the Great Lakes**

Apocorophium lacustre **has a high probability of establishment if introduced to the Great Lakes (Confidence level: High).**

Apocorophium lacustre is pollution tolerant (Evans et al. 2004), survives wide ranges of dissolved oxygen (DO) (Llansó and Sillett 2009), is salt tolerant (Wolf et al. 2009), and inhabits freshwater environments (USGS 2013). *Apocorophium lacustre* is already present in North American rivers where winter temperatures reach 1°C (Harmeson and Schnepper 1965) which suggest that it could survive the winter temperatures experienced in the Great Lakes. *Apocorophium lacustre* is a dietary generalist with a flexible diet (Llansó and Sillett 2009, Power et al. 2006) and could adjust its diet in the Great Lakes.

In other ranges where *Apocorophium lacustre* has been introduced, there are no existing control methods set to prevent the introduction or spread of *Apocorophium lacustre.* The tube-building habit of *A. lacustre* is unique but its effect is likely to be non-specific. This behavior may protect *A. lacustre* from predation by other species thereby facilitating its survival and establishment in novel habitats (Armsby and Tisch 2006, Grigorovich et al. 2008).

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
	8

- Apocorophium lacustre *is pollution tolerant (Evans et al. 2004) and inhabits the mouth of the Rhine, which is very polluted.*
- *It is found in waters with DO ranging from 1.2-6.9 mg/L (Llansó and Sillett 2009).*
- *This species is described as salt tolerant (Evans et al. 2004), from 0-30 ppt (Wolf et al. 2009), and euryhaline, but it tends to be found in the least saline environments (Faasse and van Moorsel 2003).*
- Apocorophium lacustre *also inhabits freshwater, being found in the Upper Mississippi River, Illinois River, and Ohio River (USGS 2013).*
- *It is present in the Illinois River near Peoria and Pekin, IL (USGS 2013), where the mean water temperatures in January is 1°C (Harmeson and Schnepper 1965).*
- Apocorophium lacustre *has been found in temperatures up to 31.4°C (Llansó and Sillett 2009).*

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9

Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
	8

- Apocorophium lacustre *is present in the Illinois river near Peoria and Pekin (Camp et al. 1998), where the mean water temperatures in January is 1°C (Harmeson and Schnepper 1965).*
- *This species has a recorded DO tolerance minimum of 1.2 mg/L (Llansó and Sillett 2009).*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
	7

- Apocorophium lacustre *is a detritus, suspension, and surface-deposit feeder (Llansó and Sillett 2009, Power et al. 2006).*

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	0
Unknown	U
	4

- *This species is found in low abundance in its native range (Faasse and van Moorsel 2003).*
- *Its relative abundance and frequency of occurrence increased in the Ohio River from 2004 through 2006 (from 1.7-13.8%) and the Upper Mississippi River between 2004 and 2006 (0-11%) (Grigorovich et al. 2008).*
- *In a community studied in Germany,* A. lacustre *was the second-most dense arthropod, found in 14% of samples (Ysebaert et al. 2000).*

- Apocorophium lacustre *is ecologically very similar to* Chelicorophium curvispinum *and apparently does not do well in competition with this species; it disappeared from several previously-inhabited sites following invasion by* C. curvispinum *(Noordhuis et al. 2009).*
- Apocorophium lacustre *will compete with native mussels for food and habitat space and has been known to overwhelm populations (USACE 2013).*

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
	U

- *The fecundity of* A. lacustre *is not known, but this species is in the Corophiidae Family.*
- *Brood size for other species in the Family Corophiidae (Cunha et al. 2000) include:*
    - Corophium multisetosum *ranged from 8-138 eggs/female.*
    - Corophium acherusicum *averaged 8-19 eggs/female.*
    - Corophium arenarium *ranged from 6-22 eggs/female.*
    - Corophium bonellii *ranged from 3-8 eggs/female.*
    - Corophium insidiosum *ranged from ~1-40 eggs/female.*
    - *Corophium volutator ranged from 4-70 eggs/female.*
- *Species from the Family Ampithoidae (in the Superfamily Corophioidea, containing Families Corophiidae and Ampithoidae) include the following fecundities (Best and Stachowicz 2013):*
    - Ampithoe dalli*: 30 eggs/brooding female*
    - Ampithoe lacertosa*: 40 eggs/brooding female*
    - Ampithoe sectimanus*: 20 eggs/brooding female*
    - Ampithoe valida*: 12 eggs/brooding female*

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
	3

- *Like other amphipods,* A. lacustre *broods its young, a strategy associated with enhanced colonization success.*

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	9

- Apocorophium lacustre *inhabits the Upper Mississippi River, Illinois River, and Ohio River (USGS 2013). These regions are very similar or identical to the Great Lakes region.*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- Apocorophium lacustre *inhabits the Upper Mississippi River, Illinois River, and Ohio River (USGS 2013). These regions are very similar or identical to the Great Lakes region.*
- *Also, this species inhabits regions with a wide variety of abiotic factors, a range that includes those conditions found in the Great Lakes.*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0

Unknown	U
	9

- *In its native habitat (Rhine River),* A. lacustre *is found in lower littoral and sublittoral regions and on boulder (10-50 cm diameter) substrate (Faasse and van Moorsel 2003).*
- *In the Upper Mississippi River,* A. lacustre *was found associated with hard, stable substrates – rocks and snags; in the Ohio River, where cobble and boulder habitats were less available, it colonized primarily sand and snags. This species is epibenthic and typically associated with inorganic substrates, aquatic vegetation, or zebra mussel colonies (Grigorovich et al. 2008).*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0
Unknown	U
	9

- *This species is described as salt tolerant (Evans et al. 2004), from 0-30 ppt (Wolf et al. 2009).*
- *It is found in temperatures up to 31.4°C (Llansó and Sillett 2009).*

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
	8

- Apocorophium lacustre *is a detritus, suspension, and surface-deposit feeder (Llansó and Sillett 2009, Power et al. 2006).*

- *With widespread dreissenid mussel colonies, benthic production is very high in the Great Lakes (Hecky et al. 2004).*

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Great Lakes and is not likely to be introduced	-80% total points (at end)
Unknown	U
	9

- *There is no critical species required.*

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes)	6
Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0
Unknown	U
	7

- *Amphipod invaders benefit from antecedent dreissenid invasion, which increases the structural complexity of bottom substrate for epibenthic organisms (Gonzalez and Burkart 2004, Stewart et al. 1998, van Overdijk et al. 2003). The mussels also remove seston from the water column and transform it into feces and pseudofeces consumed by amphipods (Grigorovich et al. 2008, Mordukhaĭ-Boltovskoĭ 1960, Stewart et al. 1998).*

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0
Unknown	U
	0

- *The tube-building habit of* A. lacustre *is unique but its effect is likely to be non-specific. This behavior may protect* A. lacustre *from predation by other species thereby facilitating its survival and establishment in novel habitats (Armsby and Tisch 2006, Grigorovich et al. 2008).*

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9
Frequent, moderate inocula	6
Frequent, small inocula OR infrequent, large inocula	3
Infrequent, small or moderate inocula	0
Unknown	U
	2

- *This species is quite small (up to 6 mm) and could easily be transported by recreational boaters and anglers from neighboring waters, or arrive via fouling colonies. The strength of this recreational vector is unknown but is likely relatively infrequent and small.*

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
	5

- *This species is native to the Vistula lagoon, the Rhine River, and the North Sea (Ezhova et al. 2005, Faasse and van Moorsel 2003).*
- *This species occurs in Florida waters (Camp et al. 1998), including the St. Johns River basin (Evans et al. 2004), which is the most significant river in Florida for commercial and recreational use.*
- Apocorophium lacustre *is native to the North American Atlantic coast from the Bay of Fundy, New Brunswick to the St. Johns River estuary, Florida (Bousfield 1973). It is regarded as introduced in the Gulf of Mexico and the southern North Sea coast of Europe (Bousfield 1973, Grigorovich et al. 2008, Power et al. 2006).*
- *This species has been introduced into the Upper Mississippi River, Illinois River, and Ohio River (USGS 2013).*
- *It has also been introduced to the River Werra in central Germany (Szöcs et al. 2014).*

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
	7

- *This species' range is rapidly expanding in the Upper Mississippi River system (Grigorovich et al. 2008).*

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing the establishment and spread of this species)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are	-20% total

many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	points (at end)
No control methods have been set to prevent the establishment and/or spread of this species	0
Unknown	U
	0

- *There are no existing control methods set to prevent the introduction or spread of this species.*

Establishment Potential Scorecard				
Points	**Probability for Establishment**	A. Total Points (pre-adjustment)		103
>100	High	**Adjustments**		
		B. Critical species	A*(1- 0%)	103
51-99	Moderate	C. Natural enemy	B*(1- 0%)	103
		Control measures	C*(1- 0%)	103
0-50	Low	**Potential for Establishment**		High
# of questions answered as "unable to determine"	**Confidence Level**			
0-1	High	Total # of questions unknown		1
2-5	Moderate			
6-9	Low	Confidence Level		High
>9	Very low			

Section C: Potential for Impact

<u>IMPACT POTENTIAL RESULTS</u>

Environmental: Unknown

Socio-Economic: Low

Beneficial: Low

Current research on the potential for environmental impacts to result from *Apocorophium lacustre* if introduced to the Great Lakes is inadequate to support proper assessment.

There is insufficient information available to determine whether *Apocorophium lacustre* poses a threat to other species or water quality. There are no reports on how it affects or interacts with other species. It is unknown whether this species alters the physical components of the ecosystem.

There is little or no evidence to support that *Apocorophium lacustre* has the potential for significant socio-economic impacts of introduced to the Great Lakes.

It has not been reported that *Apocorophium lacustre* poses a threat to human health or water quality. There is no evidence that this species negatively impacts infrastructure, economic sectors, recreational activities and associated tourism, or the aesthetic appeal of the areas it inhabits.

There is little or no evidence to support that *Apocorophium lacustre* has the potential for significant beneficial impacts of introduced to the Great Lakes.

It has not been indicated that *Apocorophium lacustre* can be used for the control of other organisms or improving water quality. There is no evidence to suggest that this species is commercially, recreationally, or medically valuable. It does not have significant positive ecological impacts.

POTENTIAL ENVIRONMENTAL IMPACT

NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1
Not significantly	0 √
Unknown	U

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1 √
Not significantly	0
Unknown	U

- A. lacustre *may have contributed to a decline in the native* Gammarus pseudolimnaeus*; though likely, it is uncertain (Grigorovich et al. 2008).*

- A. lacustre *is ecologically very similar to* C. curvispinum *and apparently does not do well in competition; it disappeared from several previously-inhabited sites following invasion by* C. curvispinum *(Noordhuis et al. 2009).*
- *This species was abundant in survey of South Atlantic Bight (Jacksonville, Savannah, Charleston and Wilmington) (Power et al. 2006).*
- A. lacustre *will compete with native mussels for food and habitat space and have been known to overwhelm populations (USACE 2013).*

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in the food web)	6
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	1
Not significantly	0
Unknown	U √

- A. lacustre *has been found to alter food webs and decrease faunal diversity in areas of non-native establishment (USACE 2013).*

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0
Unknown	U √

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1
Not significantly	0
Unknown	U √

E6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1
Not significantly	0
Unknown	U √

- A. lacustremay *smother native mussels (Northeast Aquatic Nuisance Species Panel 2003).*

Environmental Impact Total	**1**
Total Unknowns (U)	**4**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	Low
1	0	
0	≥2	**Unknown**
1	≥1	

POTENTIAL SOCIO-ECONOMIC IMPACT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1
Not significantly	0 √
Unknown	U

S2) Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1
Not significantly	0 √
Unknown	U

S3) Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0
Unknown	U

S4) Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

Socio-Economic Impact Total	**0**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**Low**
1	0	
0	≥2	Unknown
1	≥1	

POTENTIAL BENEFICIAL EFFECT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular effect. An "Unknown" response is appropriate if the potential for a particular effect might be inferred but has not been explicitly reported or if there is an unresolved debate about a particular effect.

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1
Not significantly	0 √
Unknown	U

B2) Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?

Yes, it is economically important to at least one of these industries	6
Yes, but its economic contribution is small	1
Not significantly	0 √
Unknown	U

B3) Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local communities and/or tourism	6
It is sometimes employed recreationally, but adds little value to local communities or	1

tourism	
Not significantly	0 √
Unknown	U

B4) Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR It is potentially important to medicine or research and is currently being or scheduled to be studied	1
Not significantly	0 √
Unknown	U

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1
Not significantly	0 √
Unknown	U

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1
Not significantly	0 √
Unknown	U

Beneficial Effect Total	**0**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**Low**

1	0	
0	≥2	Unknown
1	≥1	

Scientific Name: *Chelicorophium curvispinum*
G.O. Sars, 1895

Common Name: Caspian Mud Shrimp

Synonyms:

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: Unlikely

Hitchhiking/fouling: Unlikely

Unauthorized intentional release: Unlikely

Stocking/planting/escape from recreational culture: Unlikely

Escape from commercial culture: Unlikely

Transoceanic shipping: Moderate

Chelicorophium curvispinum **has a moderate probability of introduction to the Great Lakes (Confidence level: High).**

Potential pathway(s) of introduction: Transoceanic Shipping

Chelicorophium curvispinum is indigenous and widespread throughout the Ponto-Caspian region and recently has invaded the Baltic Sea and many large European river systems (bij de Vaate et al. 2002). In Europe, shipping—including transport by ballast water and hull fouling—has been the primary vector of dispersal of this species outside of its native range (den Hartog et al. 1992, Harris 1991, Leppäkoski and Olenin 2001, van der Velde et al. 2000). Introduction to Great Britain, for instance, likely occurred via ballast water released from ships trading with ports on the Elbe River in northern Germany (Harris 1991). The discovery of *C. curvispinum* west of the Rhine River system before it was discovered in the Rhine lends further support to shipping mediated spread (den Hartog et al. 1992), as this sort of "jump" dispersal is a common indicator of human-mediated transport (MacIsaac et al. 2001).

As Great Lakes shipping traffic commonly originates in areas where this species has become established, Ricciardi and Rasmussen (1998) identified *C. curvispinum* as a species likely to be transported to the Great Lakes via ballast water. The discovery (but not subsequent establishment) of a related Ponto-

Caspian amphipod, *Corophium mucronatum,* in a benthic sample collected from Lake St. Clair in 1997, suggests that *C. curvispinum* may at least have the potential for introduction to the Great Lakes (Grigorovich and MacIsaac 1999, Ricciardi and MacIsaac 2000). *Corophium* spp. appear to be unaffected by flow-through salinity shock experiments (increase of roughly 5 ppt from ambient salinity), but undergo ~35% mortality in empty-refill treatments after 48 hours of exposure (Johengen et al. 2005). However, given this species' physiological salinity constraints, under current mandatory ballast water regulations (saltwater flushing of at least 30 ppt), the risk of its entry into the Great Lakes has been modeled as having low likelihood (Grigorovich et al. 2003).

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100
No, this species does not occur near waters connected to the Great Lakes basin and/or is not mobile or able to be transported by wind or water.	0 √
Unknown	U

- Chelicorophium curvispinum *is native to the Ponto-Caspian region and has spread throughout Europe (bij de Vaate et al. 2002).*

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0 √
Unknown	U

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a) Is this species sold at aquarium/pet/garden stores ("brick & mortar" or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100
No, this species this species is rarely/never sold.	0 √
Unknown	U

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0 √
Unknown	U

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75

This activity is <u>likely</u> to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces), this activity <u>may</u> occur within 20 km of the basin because of the species' popularity/value.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100
No, this species is not commercially cultured in or transported through the Great Lakes region.	0 √
Unknown	U

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80 √
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40
No, this species is unlikely to be taken up in ballast, not able to survive adverse	0

environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	
Unknown	U

- *In Europe, shipping—including transport by ballast water and hull fouling—has been the primary vector of dispersal of this species outside of its native range (den Hartog et al. 1992, Harris 1991, Leppäkoski and Olenin 2001, van der Velde et al. 2000). Introduction to Great Britain, for instance, likely occurred via ballast water released from ships trading with ports on the Elbe River in northern Germany (Harris 1991). The discovery of* C. curvispinum *west of the Rhine River system before it was discovered in the Rhine lends further support to shipping mediated spread (den Hartog et al. 1992), as this sort of "jump" dispersal is a common indicator of human-mediated transport (MacIsaac et al. 2001).*
- *The discovery (but not subsequent establishment) of a related Ponto-Caspian amphipod,* Corophium mucronatum*, in a benthic sample collected from Lake St. Clair in 1997, suggests that* C. curvispinum *may at least have the potential for introduction to the Great Lakes (Grigorovich and MacIsaac 1999, Ricciardi and MacIsaac 2000).*
- Corophium *spp. appear to be unaffected by flow-through salinity shock experiments (increase of roughly 5 ppt from ambient salinity), but undergo ~35% mortality in empty-refill treatments after 48 hours of exposure (Johengen et al. 2005).*
- *However, given this species' physiological salinity constraints, under current mandatory ballast water regulations (saltwater flushing of at least 30 ppt), the risk of its entry into the Great Lakes has been modeled as having low likelihood (Grigorovich et al. 2003).*

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5 √
Yes, but this species has neither been observed in ballast/fouling ships entering the Great Lakes nor in ports in direct trade with the Great Lakes.	Score x 0.1
No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0
Unknown	U

- *As Great Lakes shipping traffic commonly originates in areas where this species has become established, Ricciardi and Rasmussen (1998) identified* C. curvispinum *as a species likely to be transported to the Great Lakes via ballast water.*

Vector Potential Scorecard					
Vector		**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind		**0**	x	**0**	Unlikely
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.		**0**	x	**0**	Unlikely
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)		**0**	x	**0**	Unlikely
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)		**0**	x	**0**	Unlikely
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)		**0**	x	**0**	Unlikely
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling		**80**	x 0.5	**40**	Moderate
Total Unknowns (U)	**0**	**Confidence Level**		High	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

ESTABLISHMENT POTENTIAL RESULTS

Status: Not established in North America, including the Great Lakes

***Chelicorophium curvispinum* has a high probability of establishment if introduced to the Great Lakes (Confidence level: Moderate).**

This species has been one of the most successful macroinvertebrate invaders in Europe, establishing populations much larger than those of any native invertebrate species within a few years of colonization (bij de Vaate et al. 2002, den Hartog et al. 1992, van den Brink et al. 1993). Densities have reached 750,000 individuals/m^2 in some areas of the Rhine (van den Brink et al. 1993). With a high fecundity (see Ecology), reproducing populations are now established throughout all major European river systems and as far west as Great Britain (bij de Vaate et al. 2002). This species is able to readily disperse through ballast water transport, ship hull fouling, passive drift, and active migration (van Riel et al. 2006, van der Velde et al. 2000), with secondary spread across Europe occurring in a pattern similar to, though at a much slower rate than, that of the zebra mussel (Tittizer et al. 1994).

Chelicorophium curvispinum is a non-specific feeder (bij de Vaate et al. 2002), filtering diatoms, organic particles, and small minerals from the water column. Its superior competitive abilities—including spatial adaptation, gregarious behavior, and relatively short lifespan and generation time—have contributed to this species' invasion success (bij de Vaate et al. 2002, van den Brink et al. 1993). Competition with other macroinvertebrate species has been well documented, most notably with the highly successful Great Lakes invader, the zebra mussel (*Dreissena polymorpha*) (see Impacts).

The water temperature (up to 31.8°C) and salinity (<6 ppt) ranges tolerated by *C. curvispinum* are well within those of the Great Lakes and have allowed this species to be extremely successful in invasions of European rivers. Furthermore, *C. curvispinum* produces overwintering populations of smaller individuals (van den Brink et al. 1993) in waters of the Ponto-Caspian basin with very similar climatic conditions to those of the Great Lakes. However, its physiological tolerance is restricted by other factors, such as ion concentrations, oxygen availability, chlorophyll *a* concentrations, flow rate, and organic pollution levels (van der Velde et al. 2000). Individuals' ability to retain and replace Na^+ and Cl^- varies among populations in different locations, and some populations have adapted to freshwater by means of lower ion permeability (Harris 1991, van der Velde et al. 2000). The changing conditions of the Rhine River throughout the 20th century, specifically increases in temperature and salinity, have created more suitable conditions for the invasion of foreign species originating in brackish waters, including *C. curvispinum (*den Hartog et al. 1992, van den Brink et al. 1993). These conditions are consistent with the physical changes forecast for the Great Lakes as a result of climate change (Rahel and Olden 2008), suggesting that this species may benefit from the resulting habitat shifts if introduced.

Chlorophyll *a* concentrations required by this species are currently present only in Lake Erie's central basin, with less than 3 μg/L typically occurring in the other lake basins (USEPA 2012). This is consistent with the predicted distribution of *C. curvispinum* in the Great Lakes according to the Genetic Algorithm for Rule-Set Production (GARP) model, which incorporates variable chlorophyll *a* levels (USEPA 2008). However, anoxic conditions have recently been present in the central basin of Lake Erie, dropping below 0.5 mg/L at certain times of year (USEPA 2012). As a result, *C. curvispinum* distribution is likely to be restricted to areas with sufficient flow rates, high dissolved oxygen levels, and high phytoplankton productivity.

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
	7

- Chelicorophium curvispinum *is found in salt, brackish, and fresh water (de Kluijver and Ingalsuo 1999). It is originally a brackish water species occurring in salinities of less than 6 ppt (Romanova 1975), with the ability to tolerate very low salinities (Bayliss and Harris 1988, Harris and Bayliss 1990, Taylor and Harris 1986b, van den Brink et al. 1993). In Black Sea lagoons and estuaries, its distribution follows the 1.5 ppt isohaline (Bortkevitch 1988).*
- *The lethal minimum oxygen concentration for* C. curvispinum *is 0.300 mg* O_2*/L (Dedyu 1980).*
- *This species is most successful in waters with relatively high ionic content and requires a minimum sodium ion (Na+) concentration of 0.5 mM (Harris and Aladin 1997).*
- *By some reports it is intolerant of heavy organic pollution levels (Harris and Muskó 1999, Jażdżewski 1980); by others it does well in organically polluted and eutrophic waters (van den Brink et al. 1993).*
- *The species is variable, adaptable and widely distributed (Crawford 1937).*

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9
Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
	8

- C. curvispinum *produces overwintering populations of smaller individuals (van den Brink et al. 1993) in waters of the Ponto-Caspian basin with very similar climatic conditions to those of the Great Lakes.*
- *The lethal minimum oxygen concentration for* C. curvispinum *is 0.300 mg* O_2*/L (Dedyu 1980).*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0

Unknown	U
	6

- Chelicorophium curvispinum *is a non-specific feeder (bij de Vaate et al. 2002), filtering diatoms, organic particles, and small minerals from the water column.*

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	0
Unknown	U
	8

- *Its superior competitive abilities—including spatial adaptation, gregarious behavior, and relatively short lifespan and generation time—have contributed to this species' invasion success (bij de Vaate et al. 2002, van den Brink et al. 1993).*
- *Competition with other macroinvertebrate species has been well documented, most notably with the highly successful Great Lakes invader, the Zebra Mussel (*Dreissena polymorpha*) (van der Velde et al. 1994). In areas where these species have colonized together,* C. curvispinum *has either greatly reduced or eliminated* D. polymorpha *populations by smothering settled individuals and larvae with a thick layer of dense, muddy material used for construction of tubes (van der Velde et al. 1994). After introduction of* C. curvispinum *to the Rhine, Zebra Mussel populations were seen to decrease from 1000s of individuals/m^2 to 100s of individuals/m^2 within four years (Paffen et al. 1994, Rajagopal et al. 1998a, van der Velde et al. 1994).*
- *This species has outcompeted the freshwater isopod* Asellus aquaticus *and several species of chironomid larvae within their native ranges in the Rhine (Kinzelbach 1997).*

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
	7

- *Bij de Vaate et al. (2002) classify* C. curvispinum *as a species with high fecundity.*

- *Reproduction in* C. curvispinum *occurs from May to October in the Black Sea (Bortkevitch 1988) and from April to September in the Baltic (van den Brink et al. 1993).*
- *The number of eggs carried by females and total female body length are correlated, ranging in the Rhine from 3 to 34 eggs (mean = 12) (van den Brink et al. 1993) and in Lake Balaton from 1 to 25 (mean = 6) (Muskó 1989, Muskó 1990).*
- *Related species, such as* C. volutator*,* C. bonnelli., C. arenarium *and* C. insidiosum *have only two generations each year. The egg clutch size of* C. curvispinum *showed a much higher increase with length than the number of eggs carried by* C. insidiosum *or* by C. arenarium*,* C. volutator *and* C. bonnelli *(van den Brink et al. 1993).*

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
	6

- *Three generations of brooded offspring are produced each year, following an overwintering period—the first in April to May, the second in June to July, and the third in September to October (den Hartog et al. 1992).*
- *In addition, this species has a short developmental time (a few weeks in summer) (van den Brink et al. 1993).*

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- *This species is a Ponto-Caspian native, a region where climatic conditions are very similar to those of the Great Lakes.*
- *The Great Lakes and Ponto-Caspian region are climatically compatible, which is one of the attributing factors to the success of Ponto-Caspian species in the Great Lakes (Reid and Orlova 2002).*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	7

- *The water temperature (up to 31.8°C) and salinity (<6 ppt) ranges tolerated by* C. curvispinum *are well within those of the Great Lakes and have allowed this species to be extremely successful in invasions of European rivers.*
- *This species is most successful in waters with relatively high ionic content and requires a minimum sodium ion (Na^+) concentration of 0.5 mM (Harris and Aladin 1997).*
- *Individuals' ability to retain and replace Na^+ and Cl^- varies among populations in different locations, and some populations have adapted to freshwater by means of lower ion permeability (Harris 1991, van der Velde et al. 2000).*
- *By some reports it is intolerant of heavy organic pollution levels (Harris and Muskó 1999, Jażdżewski 1980); by others it does well in organically polluted and eutrophic waters (van den Brink et al. 1993).*
- *It seems to prefer waters with some water movement and higher oxygen levels, though is reported in areas without these conditions (van der Velde et al. 2000).*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0
Unknown	U
	6

- *Chlorophyll* a *concentrations required by this species are currently present only in Lake Erie's central basin, with less than 3 µg/L typically occurring in the other lake basins (USEPA 2012). This is consistent with the predicted distribution of* C. curvispinum *in the Great Lakes according to the Genetic Algorithm for Rule-Set Production (GARP) model, which incorporates variable chlorophyll* a *levels (USEPA 2008).*
- *However, anoxic conditions have recently been present in the central basin of Lake Erie, dropping below 0.5 mg/L at certain times of year (USEPA 2012). As a result,* C. curvispinum *distribution is likely to be restricted to areas with sufficient flow rates, high dissolved oxygen levels, and high phytoplankton productivity.*
- *However, van den Brink et al. (1993) stated that the high organic pollution and eutrophication of the Rhine ecosystem provided ideal food for high fecundity, and found high population densities.*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0
Unknown	U
	9

- *The changing conditions of the Rhine River throughout the 20th century, specifically increases in temperature and salinity, have created more suitable conditions for the invasion of foreign species originating in brackish waters, including* C. curvispinum *(den Hartog et al. 1992, van den Brink et al. 1993).*
- *These conditions are consistent with the physical changes forecast for the Great Lakes as a result of climate change (Rahel and Olden 2008), suggesting that this species may benefit from the resulting habitat shifts if introduced.*

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
	6

- Chelicorophium curvispinum *is a non-specific feeder (bij de Vaate et al. 2002), filtering diatoms, organic particles, and small minerals from the water column.*
- *Both average clutch size (Rajagopal 1998b) and growth rate (Rajagopal 1998a) have been positively correlated with the availability of chlorophyll* a, *which leads to increased planktonic development and greater food availability (van der Velde et al. 2000). Chlorophyll* a *concentrations required by this species are currently present only in Lake Erie's central basin, with less than 3 µg/L typically occurring in the other lake basins (USEPA 2012).*

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Great Lakes and is not likely to be introduced	-80% total points (at end)
Unknown	U
	9

- *There is no critical species required by* C. curvispinum.

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes)	6
Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0
Unknown	U
	0

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0
Unknown	U
	U

- *This species is an important food source for a variety of fish species, including sculpin, eels, perch, ruffe, and pike perch, all of which are represented in the Great Lakes (van den Brink et al. 1993). Other predators include birds, crayfish, and other predatory macroinvertebrates (Biró 1974, Kelleher et al. 1998, 1999; Marguillier et al. 1998). However, the extent to which this predation will have an effect on potential populations of* C. curvispinum *in the Great Lakes is unknown.*

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9
Frequent, moderate inocula	6
Frequent, small inocula OR infrequent, large inocula	3
Infrequent, small or moderate inocula	0
Unknown	U
	U

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6

Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
	9

- *This species has been one of the most successful macroinvertebrate invaders in Europe, establishing populations much larger than those of any native invertebrate species within a few years of colonization (bij de Vaate et al. 2002, den Hartog et al. 1992, van den Brink et al. 1993). Densities have reached up to 750,000 individuals/m^2 in some areas of the Rhine (van den Brink et al. 1993). Reproducing populations are now established throughout all major European river systems and as far west as Great Britain (bij de Vaate et al. 2002).*

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
	7

- *This species is able to readily disperse through ballast water transport, ship hulls fouling, passive drift, and active migration (van Riel et al. 2006, van der Velde et al. 2000), with secondary spread across Europe occurring in a pattern similar to, though at a much slower rate than, that of the zebra mussel (Tittizer et al. 1994).*

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing the establishment and spread of this species)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent the establishment and/or spread of this species	0
Unknown	U
	0

Establishment Potential Scorecard				
Points	**Probability for Establishment**	A. Total Points (pre-adjustment)		103
>100	High	**Adjustments**		
		B. Critical species	A*(1- 0%)	103
51-99	Moderate	C. Natural enemy	B*(1- 0%)	103
		Control measures	C*(1- 0%)	103
0-50	Low	**Potential for Establishment**		High
# of questions answered as “unable to determine”	**Confidence Level**			
0-1	High	Total # of questions unknown		2
2-5	Moderate			
6-9	Low	Confidence Level		Moderate
>9	Very low			

Section C: Potential for Impact

IMPACT POTENTIAL RESULTS

Environmental: Moderate

Socio-Economic: Low

Beneficial: Moderate

***Chelicorophium curvispinum* has the potential for moderate environmental impact if introduced to the Great Lakes.**

In invasions across Europe, high densities of *C. curvispinum* have been associated with reductions in macroinvertebrate species richness (van den Brink et al. 1991, van der Velde et al. 1998). This species has outcompeted several native macroinvertebrates, including the Great Lakes invader *Dreissena polymorpha* (Zebra Mussel) (van der Velde et al. 1994). Additionally, this species has outcompeted the freshwater isopod *Asellus aquaticus* and several species of chironomid larvae within their native ranges in the Rhine (Kinzelbach 1997). Competition for food with other filter feeding species is expected if this species were to reach the Great Lakes (van den Brink et al. 1993), though competition for space (due to the smothering of settled individuals with their tube-building material and creating future unsuitable settling surface) has been the primary factor in reducing macroinvertebrate abundance in invaded areas of the Rhine (van der Velde et al. 1994). This species may have prevented the Great Lakes non-native *Echinogammarus ischnus* from forming dense populations in the Rhine (where it is native) due to the smothering of potential hard substrate settlement areas (van der Velde et al. 2000), and the production of these mud tubes has additionally led to the displacement of native filter-feeding caddisflies (*Hydropsyche* sp.) (van der Velde et al. 1994).

This species plays an important role in the food web of the Rhine as well as other invaded areas, driving prey switching among some fish predators (van der Velde et al. 2000). Due to the reduction in invertebrate diversity in areas where *C. curvispinum* has invaded, a decline in the number of predators, such as leeches, has been observed (van der Velde et al. 2000). It has been hypothesized that the prevalence of *C. curvispinum* in invaded rivers may lead to alterations of entire food webs (Ricciardi and Rasmussen 1998), although its role as a food source for predatory macroinvertebrates (e.g., as crayfish) requires further study (Rajagopal et al. 1998a).

The population explosion of *C. curvispinum* in the Rhine from 1989-1991 coincided with a decrease in the levels of total organic carbon and total suspended matter (van den Brink et al. 1993). An increase in water clarity due to particle filtration by large populations of *C. curvispinum* is thought to have expanded the euphotic zone, increasing the transfer of energy and nutrients to the benthos and leading to greater levels of benthic production (Rajagopal et al. 1998a).

There is little or no evidence to support that *Chelicorophium curvispinum* has the potential for significant socio-economic impacts if introduced to the Great Lakes.

The resulting reduction in macroinvertebrate abundance associated with *C. curvispinum* invasions may have a negative impact on the diet of native fish species; however, predation pressure on exotic amphipods changes rapidly depending upon prey availability. Hence, further biological monitoring is necessary in order to determine the full extent of the impact of *C. curvispinum* on fish diet and subsequent effect on commercial fisheries (van der Velde et al. 2000).

***Chelicorophium curvispinum* has the potential for moderate beneficial effect if introduced to the Great Lakes.**

In areas where these species have colonized together, *C. curvispinum* has either greatly reduced or eliminated *D. polymorpha* populations by smothering settled individuals and larvae with a thick layer of dense, muddy material used for construction of tubes (van der Velde et al. 1994). After introduction of *C. curvispinum* to the Rhine, zebra mussel populations were seen to decrease from 1000s of individuals/m^2 to 100s of individuals/m^2 within four years (Paffen et al. 1994, Rajagopal et al. 1998a, van der Velde et al. 1994). This species has also potentially prevented populations of another Great Lakes invader, *Echinogammarus ischnus*, from forming dense populations in the Rhine (van der Velde et al. 2000). While populations of previously established invaders in the Great Lakes may be reduced by the introduction of this species, its effectiveness as a control agent is likely to be limited due to independent negative ecological consequences.

Chelicorophium curvispinum is fed upon by many fish genera, including those with species represented in the Great Lakes (van den Brink et al. 1993). In the past, this species was intentionally introduced to large rivers in the Ponto-Caspian region to increase faunal diversity and to feed fish (Jażdżewski 1980, Karpevich 1975, Mordukhaĭ-Boltovskoĭ 1979a). However, its potential beneficial impact as a food source for commercial fisheries in the Great Lakes is unknown.

Lastly, while water clarity is increased by the presence of large populations of this species (Rajagopal 1998a), the positive impact of this effect for humans and/or native species is likely limited.

POTENTIAL ENVIRONMENTAL IMPACT

NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1
Not significantly	0 √
Unknown	U

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1 √
Not significantly	0
Unknown	U

- *In invasions across Europe, high densities of* C. curvispinum *have been associated with reductions in macroinvertebrate species richness (van den Brink et al. 1993). This species has outcompeted several native macroinvertebrates, including the Great Lakes invader* Dreissena polymorpha *(Zebra Mussel) (van der Velde et al. 1994).*
- *Additionally, this species has outcompeted the native freshwater isopod* Asellus aquaticus *and several species of chironomid larvae within their native ranges (Kinzelbach 1997).*
- *Competition for food with other filter feeding species is expected if this species were to reach the Great Lakes (van den Brink et al. 1993), though competition for space (due to the smothering of settled individuals with their tube-building material and creating future unsuitable settling surface) has been the primary factor in reducing macroinvertebrate abundance in invaded areas of the Rhine (van der Velde et al. 1994).*
- *This species may have prevented the Great Lakes non-native* Echinogammarus ischnus *from forming dense populations in the Rhine (where it is native) due to the smothering of potential hard substrate settlement areas (van der Velde et al. 2000).*
- *The production of these mud tubes has additionally led to the displacement of native filter-feeding caddisflies (*Hydropsyche *sp.) (van der Velde et al. 1994).*

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in	6

the food web)	
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	1 √
Not significantly	0
Unknown	U

- *This species plays an important role in the food web of the Rhine as well as other invaded areas, driving prey switching among some fish predators (van der Velde et al. 2000).*
- *Due to the reduction in invertebrate abundance in areas where* C. curvispinum *has invaded, a decline in the number of predators, such as leeches, has been observed (van der Velde et al. 2000).*
- *It has been hypothesized that the prevalence of* C. curvispinum *in invaded rivers may lead to alterations of entire food webs (Ricciardi and Rasmussen 1998), although its role as a food source for predatory macroinvertebrates (e.g., crayfish) requires further study (Rajagopal et al. 1998a).*

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0 √
Unknown	U

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1 √
Not significantly	0
Unknown	U

- *The population explosion of* C. curvispinum *in the Rhine from 1989-1991 coincided with a decrease in the levels of total organic carbon and total suspended matter (van den Brink et al. 1993).*
- *An increase in water clarity due to particle filtration by large populations of* C. curvispinum *is thought to have expanded the euphotic zone, increasing the transfer of energy and nutrients to the benthos and leading to greater levels of benthic production (Rajagopal et al. 1998a).*

E6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical	6

ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1
Not significantly	0 √
Unknown	U

Environmental Impact Total	**3**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	**<u>Moderate</u>**
0	0-1	Low
1	0	
0	≥2	Unknown
1	≥1	

<u>POTENTIAL SOCIO-ECONOMIC IMPACT</u>

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1
Not significantly	0 √
Unknown	U

S2) Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1

Not significantly	0 √
Unknown	U

S3) Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0 √
Unknown	U

S4) Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0
Unknown	U √

- *The resulting reduction in macroinvertebrate abundance associated with* C. curvispinum *invasions may have a negative impact on the diets of native fish species, however, predation pressure on exotic amphipods changes rapidly depending upon prey availability. Hence, further biological monitoring is necessary in order to determine the full extent of the impact of* C. curvispinum *on fish diet and subsequent effect on commercial fisheries (van der Velde et al. 2000).*

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

Socio-Economic Impact Total	**0**
Total Unknowns (U)	**1**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**<u>Low</u>**
1	0	
0	≥2	Unknown
1	≥1	

POTENTIAL BENEFICIAL EFFECT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular effect. An "Unknown" response is appropriate if the potential for a particular effect might be inferred but has not been explicitly reported or if there is an unresolved debate about a particular effect.

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1 √
Not significantly	0
Unknown	U

- *In areas where these species have colonized together,* C. curvispinum *has either greatly reduced or eliminated* D. polymorpha *populations by smothering settled individuals and larvae with a thick layer of dense, muddy material used for construction of tubes (van der Velde et al. 1994). After introduction of* C. curvispinum *to the Rhine, Zebra Mussel populations were seen to decrease from 1000s of individuals /m^2 to 100s of individuals/m^2 within four years (Paffen et al. 1994, Rajagopal et al. 1998a, van der Velde et al. 1994, van der Velde et al. 1998).*
- *This species has also potentially prevented populations of another Great Lakes invader,* Echinogammarus ischnus, *from forming dense populations in the Rhine (van der Velde et al. 2000).*
- *While populations of previously established invaders in the Great Lakes may be reduced by the introduction of this species, its effectiveness as a control agent is likely to be limited due to independent negative ecological consequences.*

B2) Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?

Yes, it is economically important to at least one of these industries	6
Yes, but its economic contribution is small	1

Not significantly	0 √
Unknown	U

- Chelicorophium curvispinum *is fed upon by many fish genera, including those with species represented in the Great Lakes (van den Brink et al. 1993). In the past, this species was intentionally introduced to large rivers in the Ponto-Caspian region to increase faunal diversity and to feed fish (Jażdżewski 1980, Karpevich 1975, Mordukhaĭ-Boltovskoĭ 1979). However, its potential beneficial impact as a food source for commercial fisheries in the Great Lakes is unknown.*

B3) Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local communities and/or tourism	6
It is sometimes employed recreationally, but adds little value to local communities or tourism	1
Not significantly	0 √
Unknown	U

B4) Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR It is potentially important to medicine or research and is currently being or scheduled to be studied	1
Not significantly	0 √
Unknown	U

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1 √
Not significantly	0
Unknown	U

- *While water clarity is increased by the presence of large populations of this species (Rajagopal 1998a), the positive impact of this effect for humans and/or native species is likely limited.*

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1

Not significantly	0 √
Unknown	U

Beneficial Effect Total	**2**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	**Moderate**
0	0-1	Low
1	0	
0	≥2	Unknown
1	≥1	

Scientific Name: *Dikerogammarus haemobaphes*
Eichwalk, 1841

Common Name: Small-humped Amphipod

Synonyms:

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: Unlikely

Hitchhiking/fouling: Unlikely

Unauthorized intentional release: Unlikely

Stocking/planting/escape from recreational culture: Unlikely

Escape from commercial culture: Unlikely

Transoceanic shipping: Moderate

***Dikerogammarus haemobaphes* has a moderate probability of introduction to the Great Lakes (Confidence level: High).**

Potential pathway(s) of introduction: Transoceanic Shipping

Dikerogammarus haemobaphes has been proposed to be able to survive partial to complete ballast water exchange due to one reported natural occurrence in 17 ppt salinity waters (Grigorovich et al. 2003), but other estimates of this species' salinity tolerance are more restrictive (0-8 ppt) (Ponomareva 1976). Based on the former, Grigorovich et al. (2003) assessed *D. haemobaphes* as having a high Great Lakes invasion risk mediated by both BOB and NOBOB vessels. However, the closely related European invader *D. villosus* exhibited 0% survival after 24 hours in 34 PSU empty-refill and flow-through salinity treatments (Santagata et al. 2008), suggesting that *D. haemobaphes* may be similarly impacted by current ballast water regulations.

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100
No, this species does not occur near waters connected to the Great Lakes basin and/or is not mobile or able to be transported by wind or water.	0 √
Unknown	U

- Dikerogammarus haemobaphes *is native to the Ponto-Caspian region and now present across European rivers and into the Baltic Sea (bij de Vaate et al. 2002).*

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0 √
Unknown	U

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a) Is this species sold at aquarium/pet/garden stores ("brick & mortar" or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100
No, this species this species is rarely/never sold.	0 √
Unknown	U

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0 √
Unknown	U

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is likely to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces), this activity may occur within 20 km of the basin because of the species' popularity/value.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100
No, this species is not commercially cultured in or transported through the Great Lakes region.	0 √
Unknown	U

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80 √
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40
No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0
Unknown	U

- Dikerogammarus haemobaphes *has been proposed to be able to survive partial to complete ballast water exchange due to one reported natural occurrence in 17 ppt salinity waters (Grigorovich et al. 2003), but other estimates of this species' salinity tolerance are more restrictive (0-8 ppt) (Ponomareva 1976). Based on the former, Grigorovich et al. (2003) assessed* D. haemobaphes *as having a high Great Lakes invasion risk mediated by both BOB and NOBOB vessels.*
- *However, the closely related European invader* D. villosus *exhibited 0% survival after 24 hours in 34 PSU empty-refill and flow-through salinity treatments (Santagata et al. 2008), suggesting that* D. haemobaphes *may be similarly impacted by current ballast water regulations.*

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5 √
Yes, but this species has neither been observed in ballast/fouling ships entering the Great Lakes nor in ports in direct trade with the Great Lakes.	Score x 0.1

No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0
Unknown	U

- *This species has expanded its range from the Ponto-Caspian basin and is now present in coastal waters of the Baltic Sea, as well as connecting European river systems (bij de Vaate et al. 2002).*

Vector Potential Scorecard				
Vector	**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind	**0**	x	**0**	Unlikely
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.	**0**	x	**0**	Unlikely
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)	**0**	x	**0**	Unlikely
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)	**0**	x	**0**	Unlikely
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)	**0**	x	**0**	Unlikely
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling	**80**	x 0.5	**40**	Moderate
Total Unknowns (U)	**0**	**Confidence Level**	High	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

ESTABLISHMENT POTENTIAL RESULTS

Status: **Not established in North America, including the Great Lakes**

***Dikerogammarus haemobaphes* has a high probability of establishment if introduced to the Great Lakes (Confidence level: Moderate).**

The climatic conditions of the native (Ponto-Caspian) and introduced (Baltic) ranges of *D. haemobaphes* are very similar to those of the Great Lakes. While *D. haemobaphes* is able survive in moderately wide temperature and salinity ranges, as well as hypoxic conditions, it is primarily a freshwater, riverine species. Its westward spread through all major European river systems connecting the Ponto-Caspian with the Baltic may have been limited by salinity levels to inland water courses (bij de Vaate et al. 2002). Nevertheless, its physiological tolerances are well within conditions occurring in the Great Lakes. Increased salinization as a potential effect of climate change (Rahel and Olden 2008) may be inconsequential to this species' establishment in the Great Lakes, as it tolerates salinities up to 8 ppt (Ponomareva 1976). Arbačiauskas (2002) hypothesized that oxygen concentration is the principal limiting factor in determining the survival and sustainability of populations of Ponto-Caspian amphipods. Therefore, anoxic conditions, as present in the central basin of Lake Erie (Summers 2001), may prevent *D. haemobaphes* from establishing in some regions of the Great Lakes.

Feeding plasticity, high reproductive capacity, relatively small eggs, short egg development time, fast sexual maturation, brooding, and production of multiple generations per year are factors thought to contribute to the invasion success of this species (Bacela et al. 2009, bij de Vaate et al. 2002). *Dikerogammarus haemobaphes* fecundity is moderate compared to that of the invasive gammarids *D. villosus* and *P. robustoides* (Bacela et al. 2009), but it is high in relation to invasive European gammarids as a group (Grabowski et al. 2007a). The autumn generation typically overwinters, but in thermally polluted waters (e.g., hydroelectric cooling water discharge), this species may reproduce year round (Kiticyna 1980); therefore, warming waters as a result of climate change could be beneficial to its invasion success.

Regarding interspecific interactions, *D. haemobaphes* has outcompeted and displaced native European gammarids, but it has also experienced declines in European waterways following expansion of the related invasive amphipod *Dikerogammarus villosus* (Jażdżewski et al. 2004, Jażdżewski et al. 2005, Kinzler et al. 2009). *Dikerogammarus haemobaphes* constitutes a food base for multiple fish genera (Grabowska and Grabowski 2005, Kelleher et al. 1998, Kelleher et al. 2000, Kostrzewa and Grabowski 2003), though the extent to which this predation will have an effect on potential populations in the Great Lakes is unknown.

Invasive dreissenid mussels are likely to facilitate the establishment of *D. haemobaphes* in the Great Lakes, as this amphipod preferentially colonizes living zebra mussel shells over other substrate types, including empty shells and stones, in the Ponto-Caspian and other newly invaded regions.

The dispersal rate of *D. haemobaphes* across Europe is similar to that of many other Ponto-Caspian invasive amphipods (*D. villosus*), spreading across the entire European continent in roughly 50 years (bij de Vaate et al. 2002).

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
	6

- Dikerogammarus haemobaphes *is able to tolerate a relatively wide temperature range (6-30°C) (Kiticyna 1980).*
- *Although Grigorovich et al. (2003) listed* D. haemobaphes *as occurring naturally in waters of 17 ppt salinity, this species is most likely restricted to 0-8 ppt (Ponomareva 1976). It is more commonly found near mouths of freshwater rivers (typically 1-1.5 PSU) than in more saline waters (2-8 PSU) (Grabowski et al. 2006, Jażdżewski et al. 2002, Jazdewski et al. 2004, Jażdżewski et al. 2005).*
- *The lethal minimum oxygen concentration for* D. haemobaphes *is 0.345 mg O_2/L; while such conditions are considered hypoxic, several other Ponto-Caspian amphipods invaders in the Baltic Sea can tolerate even lower oxygen concentrations (Dedyu 1980).*

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9
Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
	8

- *This species is able to overwinter in its native European range (Ponto-Caspian) by producing an autumn generation that survives to reproduce in the following spring (Bacela et al. 2009).*
- *The lethal minimum oxygen concentration for* D. haemobaphes *is 0.345 mg O_2/L (Dedyu 1980).*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0

Unknown	U
	9

- Dikerogammarus haemobaphes *is a dietary generalist (bij de Vaate et al. 2002), feeding on detritus, sediments, unicellular and filamentous algae, and other small crustaceans.*
- *Its predation intensity on animal food sources such as chironomids, oligochaetes, crustaceans, and mayflies increases during the summer months when water temperatures are higher (van der Velde et al. 2009).*
- *Feeding plasticity is one aspect that may explain its rapid expansion across Europe (Bacela et al. 2009).*

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	0
Unknown	U
	5

- Dikerogammarus haemobaphes *has outcompeted and displaced native European gammarids, but it has also experienced declines (been outcompeted itself) in European waterways following expansion of the related invasive* D. villosus *(Kinzler et al. 2009).*

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
	6

- Dikerogammarus haemobaphes *fecundity is moderate compared to that of the invasive gammarids* D. villosus *and* P. robustoides *(Bacela et al. 2009), but it is high in relation to invasive European gammarids as a group (Grabowski et al. 2007).*

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
	7

- *High reproductive capacity, relatively small eggs, short egg development time, fast sexual maturation, brooding, and production of multiple generations per year are factors thought to contribute to the invasion success of this species in Europe (Bacela et al. 2009, bij de Vaate et al. 2002).*

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- *The climatic conditions of the native (Ponto-Caspian) and introduced (Baltic) ranges of* D. haemobaphes *are very similar to those of the Great Lakes.*
- *The Great Lakes and Ponto-Caspian region are climatically compatible, which is one of the attributing factors to the success of Ponto-Caspian species in the Great Lakes (Reid and Orlova 2002).*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0

Unknown	U
	8

- Dikerogammarus haemobaphes *is euryoecious (adapted to varied ecological conditions), preferring to inhabit solid substrates, macrophytes, and filamentous algae in large rivers and lakes (Kiticyna 1980, Muskó 1994).*
- *It is most commonly found near mouths of freshwater rivers (typically 1-1.5 PSU) than in more saline waters (2-8 PSU) (Grabowski et al. 2006, Jażdżewski et al. 2002, Jażdżewski et al. 2004, Jażdżewski et al. 2005).*
- *Abiotic factors and climatic conditions of the native and introduced ranges of this species are quite similar to the Great Lakes, making the region compatible (Grigorovich et al. 2003, Reid and Orlova 2002).*
- *Great Lakes underwent similar anthropogenic eutrophication as the Ponto-Caspian region (Reid and Orlova 2002). Surface water temperature is similar between the Great Lakes and Ponto-Caspian seas (Grigorovich et al. 2003, Reid and Orlova 2002, USEPA 2008).*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0
Unknown	U
	8

- *Arbačiauskas (2002) hypothesized that oxygen concentration is the principal limiting factor in determining the survival and sustainability of populations of Ponto-Caspian amphipods. Therefore, anoxic conditions, as present in the central basin of Lake Erie (Summers 2001), may prevent* D. haemobaphes *from establishing in some regions of the Great Lakes.*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0
Unknown	U
	7

- *In thermally polluted waters (e.g., hydroelectric cooling water discharge), this species may reproduce year round (Kiticyna 1980); therefore, warming waters as a result of climate change could be beneficial to its invasion success.*

- *Increased salinization as a potential effect of climate change (Rahel and Olden 2008) may be inconsequential to this species' establishment in the Great Lakes, as it tolerates salinities up to 8 ppt (Ponomareva 1976).*

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
	9

- *This species is a dietary generalist (bij de Vaate et al. 2002), feeding on detritus, sediments, unicellular and filamentous algae, and other small crustaceans. None of these food sources are limiting in the Great Lakes.*

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Great Lakes and is not likely to be introduced	-80% total points (at end)
Unknown	U
	9

- *There is no critical species required by* D. haemobaphes.

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes)	6
Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0
Unknown	U
	9

- Dikerogammarus haemobaphes *is frequently found in association with another Ponto-Caspian invader,* Dreissena polymorpha*, preferring to settle on living zebra mussel shells over other substrate types, including empty shells and stones, in the Ponto-Caspian and other newly invaded regions (bij de Vaate et al. 2002, Kobak et al. 2009, Muskó 1993, Wawrzyniak- Wydrowska and Gruszka 2005).*
- *Dreissenid shell surface properties are thought to attract* D. haemobaphes*, with a distinct preference shown for living mussels over empty shells as well as clean shells over varnished shells (Kobak et al. 2009).*
- *Additionally, the living mussel shells serve as a better habitat for prey items, including chironomids (Botts et al. 1996, Mörtl and Otto-Rothhaupt 2003, Ricciardi et al. 1997, Stewart et al. 1998).*

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0
Unknown	U
	U

- Dikerogammarus haemobaphes *constitutes a food base for multiple fish genera (Grabowska and Grabowski 2005, Kelleher et al. 1998, Kelleher et al. 2000, Kostrzewa and Grabowski 2003), though the extent to which this predation will have an effect on potential populations in the Great Lakes is unknown.*

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9
Frequent, moderate inocula	6
Frequent, small inocula OR infrequent, large inocula	3
Infrequent, small or moderate inocula	0
Unknown	U
	U

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
	9

- Dikerogammarus haemobaphes *was first observed in a non-native location in 1976, when it migrated up the Danube River through the southern corridor and arrived in the German section of the upper Danube (Tittizer 1996). It was subsequently observed in the Main-Danube canal in 1993 (Schleuter et al. 1994), through which it migrated to the North Sea basin via the Rhine River (Schöll et al. 1995). In 1997, this species was first discovered in Poland in the Vistula River (Konopacka 1998). Around this time, it was also discovered in the Notec and Bug rivers, tributaries of the Oder and Vistula rivers, respectively (Jażdżewski and Konopacka 2000, Jażdżewski and Konopacka 2002, Jażdżewski et al. 2002).* Dikerogammarus haemobaphes *was observed in the central and southern corridors of the Volga River, as well as the upper Volga basin, for the first time around the year 2000 and quickly became abundant (L'vova et al. 1996, Jażdżewski et al. 2004). It is now also present in the Great Masurian Lakes (Jażdżewski 2003) and in a small mesotrophic lake in the Vistula valley (Grabowski and Bacela 2005).*
- *The westward spread of* D. haemobaphes *through all major European river systems connecting the Ponto-Caspian with the Baltic may have been limited by salinity levels to inland water courses (bij de Vaate et al. 2002).*

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
	7

- *The dispersal rate of* D. haemobaphes *across Europe is similar to that of many other Ponto-Caspian invasive amphipods (e.g.,* D. villosus*), spreading across the entire European continent in roughly 50 years (bij de Vaate et al. 2002).*

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing the establishment and spread of this species)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent the establishment and/or spread of this species	0
Unknown	U
	0

Establishment Potential Scorecard				
Points	**Probability for Establishment**	A. Total Points (pre-adjustment)		115
>100	High	**Adjustments**		
		B. Critical species	A*(1- 0%)	115
51-99	Moderate	C. Natural enemy	B*(1- 0%)	115
		Control measures	C*(1- 0%)	115

0-50	Low	**Potential for Establishment**	High
# of questions answered as “unable to determine”	**Confidence Level**		
0-1	High	Total # of questions unknown	2
2-5	Moderate		
6-9	Low	Confidence Level	Moderate
>9	Very low		

Section C: Potential for Impact

IMPACT POTENTIAL RESULTS

Environmental: Unknown

Socio-Economic: Low

Beneficial: Low

Current research on the potential for environmental impact of *Dikerogammarus haemobaphes* if introduced to the Great Lakes is inadequate to support proper assessment.

Upon introduction to new waterways, *D. haemobaphes* has outcompeted native European gammarids, including displacing *Chaetogammarus ischnus* in the lower Vistula Lagoon (Jażdżewski et al. 2004, 2005). Additionally, *D. haemobaphes* is a vector of gregarines, a group of unicellular parasites that infect the intestines of invertebrates (Codreanu-Balcescu 1995). However, the transfer of these parasites to native species is unknown (Grabowski et al. 2007b).

There is little or no evidence to support that *Dikerogammarus haemobaphes* has the potential for significant socio-economic impacts if introduced to the Great Lakes.

It has not been reported that *Dikerogammarus haemobaphes* poses a threat to human health or water quality. There is no evidence that this negatively impacts infrastructure, economic sectors, recreational activities and associated tourism, or the aesthetic appeal of the areas it inhabits.

There is little or no evidence to support that *Dikerogammarus haemobaphes* has the potential for significant beneficial effects if introduced to the Great Lakes.

Dikerogammarus haemobaphes constitutes a food base for perches, gobies, and eels (Grabowska and Grabowski 2005, Kelleher et al. 1998, Kelleher et al. 2000, Kostrzewa and Grabowski 2003). It was intentionally stocked in large European rivers prior to the 1970s to enhance the fish fauna (Karpevich 1975, Jażdżewski 1980, bij de Vaate et al. 2002).

POTENTIAL ENVIRONMENTAL IMPACT

NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1
Not significantly	0
Unknown	U √

- Dikerogammarus haemobaphes *is a vector of gregarines, a group of unicellular parasites that infect the intestines of invertebrates (Codreanu-Balcescu 1995). However, the transfer of these parasites to native species is unknown (Grabowski et al. 2007b).*

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1 √
Not significantly	0
Unknown	U

- *Upon introduction to new waterways,* D. haemobaphes *has outcompeted native European gammarids, including displacing* Chaetogammarus ischnus *in the lower Vistula Lagoon (Jażdżewski et al. 2004, Jażdżewski et al. 2005).*

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in the food web)	6
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	1
Not significantly	0 √
Unknown	U

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0 √
Unknown	U

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1
Not significantly	0 √
Unknown	U

E6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1
Not significantly	0 √
Unknown	U

Environmental Impact Total	**1**
Total Unknowns (U)	**1**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate

0	0-1	Low
1	0	
0	≥2	**Unknown**
1	≥1	

POTENTIAL SOCIO-ECONOMIC IMPACT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1
Not significantly	0 √
Unknown	U

S2) Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1
Not significantly	0 √
Unknown	U

S3) Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0 √
Unknown	U

S4) Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0 √

Unknown	U

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

Socio-Economic Impact Total	**0**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**<u>Low</u>**
1	0	
0	≥2	Unknown
1	≥1	

<u>POTENTIAL BENEFICIAL EFFECT</u>

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular effect. An "Unknown" response is appropriate if the potential for a particular effect might be inferred but has not been explicitly reported or if there is an unresolved debate about a particular effect.

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1
Not significantly	0 √
Unknown	U

B2) Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?

Yes, it is economically important to at least one of these industries	6
Yes, but its economic contribution is small	1 √
Not significantly	0
Unknown	U

- Dikerogammarus haemobaphes *constitutes a food base for perches, gobies, and eels (Grabowska and Grabowski 2005, Kelleher et al. 1998, Kelleher et al. 2000, Kostrzewa and Grabowski 2003).*
- *This species was intentionally stocked in large European rivers prior to the 1970s to enhance the fish fauna (bij de Vaate et al. 2002, Karpevich 1975, Jażdżewski 1980).*

B3) Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local communities and/or tourism	6
It is sometimes employed recreationally, but adds little value to local communities or tourism	1
Not significantly	0 √
Unknown	U

B4) Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR It is potentially important to medicine or research and is currently being or scheduled to be studied	1
Not significantly	0 √
Unknown	U

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of	6

humans and/or native species	
Yes, but positive impact for humans or native species is considered negligible	1
Not significantly	0 √
Unknown	U

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1
Not significantly	0 √
Unknown	U

Beneficial Effect Total	**1**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**Low**
1	0	
0	≥2	Unknown
1	≥1	

Scientific Name: *Dikerogammarus villosus* Sowinsky, 1894

Common Name: Killer Shrimp

Synonyms:

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: Unlikely

Hitchhiking/fouling: Unlikely

Unauthorized intentional release: Unlikely

Stocking/planting/escape from recreational culture: Unlikely

Escape from commercial culture: Unlikely

Transoceanic shipping: Moderate

***Dikerogammarus villosus* has a moderate probability of introduction to the Great Lakes (Confidence level: High).**

Potential pathway(s) of introduction: Transoceanic Shipping

Dikerogammarus villosus is native to the Ponto-Caspian region, an invasion donor "hot spot," and has expanded its range throughout Western Europe. Due to its high tolerance to varying salinities, oxygen concentrations, and temperatures, *D. villosus* has been proposed to be a highly likely candidate for introduction to the Great Lakes via ballast water transport from European ships (Bruijs et al. 2001, Dick and Platvoet 2001, Dick et al. 2002, Grigorovich et al. 2003, MacIsaac 1999, Mills et al. 1993, Ricciardi and Rasmussen 1998). However, under current mandatory ballast water regulations (saltwater flushing of at least 30 ppt), the risk of entry for this species is likely reduced. Santagata et al. (2008) report 0% *D. villosus* survival after exposure to full strength seawater (34 PSU) for 24 hours in both empty-refill and flow-through ballast treatments. As a benthic amphipod able to bury in sediment (where conditions may be less saline), less stringent ballast water flushing and/or exchange is likely to have diminished effectiveness.

While there has been mention of hull fouling of ocean-going vessels as an alternate pathway of introduction (Devin and Beisel 2006), supporting evidence is unavailable at this time.

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100
No, this species does not occur near waters connected to the Great Lakes basin and/or is not mobile or able to be transported by wind or water.	0 √
Unknown	U

- Dikerogammarus villosus *is native to the Ponto-Caspian region and has spread throughout western Europe (bij de Vaate et al. 2002).*

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0 √
Unknown	U

- *At present, it is unlikely for* D. villosus *to be introduced into the Great Lakes via hitchhiking on recreational gear or boat structures that enter the Lakes from other parts of the United States or Canada. However, as this was the most probable vector for its introduction in Lake Garda, Italy—tourist boats coming from central European lakes (Casellato et al. 2005)—it could become a potential vector if the species arrives and becomes established on the North American continent.*

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a) Is this species sold at aquarium/pet/garden stores ("brick & mortar" or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100
No, this species this species is rarely/never sold.	0 √
Unknown	U

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0 √
Unknown	U

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is likely to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces), this activity may occur within 20 km of the basin because of the species' popularity/value.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100
No, this species is not commercially cultured in or transported through the Great Lakes region.	0 √
Unknown	U

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80 √
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40
No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0
Unknown	U

- *Due to its high tolerance to varying salinities, oxygen concentrations, and temperatures,* D. villosus *has been proposed to be a highly likely candidate for introduction to the Great Lakes via ballast water transport from European ships (Bruijs et al. 2001, Dick and Platvoet 2001, Dick et al. 2002, Grigorovich et al. 2003, MacIsaac 1999, Mills et al. 1993, Ricciardi and Rasmussen 1998).*
- *Under current mandatory ballast water regulations (saltwater flushing of at least 30 ppt), the risk of entry for this species is likely reduced. Santagata et al. (2008) report 0%* D. villosus *survival after exposure to full strength seawater (34 PSU) for 24 hours in both empty-refill and flow-through ballast treatments.*
- *As a benthic amphipod able to bury in sediment (where conditions may be less saline), less stringent ballast water flushing and/or exchange is likely to have diminished effectiveness.*

- *While there has been mention of hull fouling of ocean-going vessels as an alternate pathway of introduction (Devin and Beisel 2006), supporting evidence is unavailable at this time.*

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5 √
Yes, but this species has neither been observed in ballast/fouling ships entering the Great Lakes nor in ports in direct trade with the Great Lakes.	Score x 0.1
No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0
Unknown	U

- Dikerogammarus villosus *is native to the Ponto-Caspian region, an invasion donor "hot spot," and has expanded its range throughout Western Europe. Ballast water of transoceanic shipping has been considered a likely invasion vector to the Great Lakes (Dick et al. 2002).*

Vector Potential Scorecard				
Vector	**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind	**0**	x	**0**	Unlikely
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.	**0**	x	**0**	Unlikely
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)	**0**	x	**0**	Unlikely
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)	**0**	x	**0**	Unlikely
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)	**0**	x	**0**	Unlikely
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling	**80**	x 0.5	**40**	Moderate
Total Unknowns (U)	**0**	**Confidence Level**	High	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

ESTABLISHMENT POTENTIAL RESULTS

Status: **Not established in North America, including the Great Lakes**

***Dikerogammarus villosus* has a high probability of establishment if introduced to the Great Lakes (Confidence level: High**).

Dikerogammarus villosus has not yet been recorded in the Great Lakes, but this species has a history of successful invasions throughout Europe (Devin et al. 2001). In addition to a physiology that facilitates ballast water transport (relatively wide temperature and salinity tolerance), this species possesses many advantageous life history traits conducive to successful invasions, including: short generation time, rapid growth rate, female-biased sex ratio, early sexual maturity, high fecundity, brooding, production of multiple generations per year, exceptional predatory and competitive capabilities, ecological plasticity, and large size compared to related species (bij de Vaate et al. 2002, Bruijs et al. 2001, Devin and Beisel 2006, Devin et al. 2004, Dick and Platvoet 2000, Wijnhoven et al. 2003). These characteristics, combined with abundant potential food sources, make *D. villosus* a species expected to have high potential for spread if introduced to the Great Lakes ecosystem (Devin et al. 2003 and 2004, Dick and Platvoet 2000, Dick et al. 2002, Grigorovich et al. 2003, MacIsaac et al. 2001, Ricciardi and Rasmussen 1998). Its propagule pressure during the shipping season (May-October) is likely to be high, as this period overlaps with *D. villosus'* reproductive peak (May/June) (Pöckl 2009). Following introduction, this species is also likely to spread by hitchhiking on recreational gear, boats, or trailers, as was a probable vector for its introduction to Lake Garda, Italy (Casellato et al. 2005).

Climatic conditions (e.g., temperature, precipitation, seasonality) and abiotic factors (e.g., pollution, water temperature, salinity, pH, nutrient levels and current) relevant to the success of *D. villosus* in its native and introduced ranges are similar to those in the Great Lakes. One such adaptation enabling this species to overwinter is that its oxygen demand is greatly reduced at temperatures around 1°C (Wijnhoven et al. 2003).

A strong ecological connection exists between *D. villosus* and other Great Lakes invaders from the Ponto-Caspian, such as *Dreissena polymorpha*; under the theory of "invasional meltdown," it has been predicted that invasion of the killer shrimp will be facilitated by these companion species (Devin et al. 2003, Dick and Platvoet 2000 and 2002, Ricciardi and Rasmussen 1998). For instance, beds of *D. polymorpha* may facilitate establishment of this large amphipod by providing colonization substrate (Devin et al. 2003, Dick et al. 2002). *Dikerogammarus villosus* also exhibits variable morphology and coloration (Nesemann et al. 1995, Pjatakova and Tarasov 1996), which could facilitate its concealment and establishment in new environments.

Increased water temperature as a result of climate change is likely to enhance breeding, as has been observed with its relative *D. haemobaphes* (Kiticyna 1980). However, although *D. villosus* has broad environmental tolerances, particularly with respect to high salinity, it is not known to survive in waters warmer than 35°C and may not typically survive prolonged exposure to temperatures in excess of 27°C (Bruijs et al. 2001, Maazouzi et al. 2011, van der Velde et al. 2009, Wijnhoven et al. 2003). This species prefers temperatures from 5 to 15°C and exhibits a limited potential to adjust to waters warmer than 20°C (Maazouzi et al. 2011).

The dispersal rate of this species across Europe is similar to that of many other Ponto-Caspian invasive amphipods (e.g., *Dikerogammarus haemobaphes*), spreading across the entire European continent in roughly 50 years (bij de Vaate et al. 2002).

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
	7

- Dikerogammarus villosus *is able to tolerate temperatures from 0-35°C, with an optimal temperature range of 5-15°C (Bruijs et al. 2001, Maazouzi et al. 2011, van der Velde et al. 2009, Wijnhoven et al. 2003).*
- *It naturally occurs at 17 ppt but can tolerate salinities ranging from 0 to 20 ppt (Bruijs et al. 2001, Grigorovich et al. 2003). While able to survive short exposure (3 hours) to full strength seawater,* D. villosus *experiences 100% mortality when exposed to 34 PSU (practical salinity units) for 24 hours (Santagata et al. 2008).*
- *The minimum lethal oxygen concentration for this species is 0.380 mg O_2/L; while such conditions are considered hypoxic, other Ponto-Caspian amphipods invaders in the Baltic Sea can tolerate even lower oxygen concentrations (Dedyu 1980).*

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9
Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but	3

it is not known as an overwintering species)	
Unlikely	0
Unknown	U
	8

- *Oxygen demand for this species is greatly reduced at temperatures around 1°C (Wijnhoven et al. 2003).*
- *Due to the climatic similarities between the Great Lakes and Ponto-Caspian regions (Reid and Orlova 2002) this species most likely endures similar overwintering conditions in its native range.*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
	9

- Dikerogammarus villosus *is an omnivorous predator of many macroinvertebrates, including other gammarids, and is also able to collect detritus and to filter out suspended algae (Mayer et al. 2008). It exhibits a cannibalistic nature by occasionally eating conspecific newborns and weak adults (Devin and Beisel 2006, Dick and Platvoet 2000, Dick et al. 2002, Mordukhaĭ-Boltovskoĭ 1979a, Platvoet et al. 2009).*

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	0
Unknown	U
	9

- Dikerogammarus villosus *is a fierce predator and superior competitor. It eats and displaces other amphipods and is predicted to greatly reduce amphipod diversity in a variety of North American freshwater habitats, particularly in the Great Lakes where its invasion has been facilitated by an "invasional meltdown" (Dick et al. 2002, Dick and Platvoet 2000, Ricciardi and Rasmussen 1998).*
- *In the Netherlands,* D. villosus *has threatened the European native amphipod species* Gammarus duebeni*, but it has also controlled populations of the North American invader* G. tigrinus *(Dick and Platvoet 2000).*

- Dikerogammarus villosus *is thought to have displaced additional* Dikerogammarus *invaders (*D. bispinosus *and* D. haemobaphes*) in the Danube River (Müller et al. 2002). This species also has the potential to consume eggs or juvenile stages of small fish, causing potential concern for game fish populations if introduced to the Great Lakes (Devin and Beisel 2006).*

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
	8

- Dikerogammarus villosus *is reproductive year round in its native range (Devin et al. 2004, Mordukhaĭ-Boltovskoĭ 1979a). Mean fecundity is around 30 eggs per female; however, females can to lay up to 194 eggs clutch, giving this species the highest fecundity of the European gammarids (Devin et al. 2004, Kley and Maier 2003, Kley and Maier 2006, Pöckl 2007).*

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
	7

- *Rapid growth and sexual maturation (leading to short generation time), brooding, production of multiple generations per year, and a female-biased sex ratio increasing reproductive capacity of populations are factors thought to contribute to the invasion success of this species in Europe (bij de Vaate et al. 2002, Devin et al. 2004).*

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- *The climatic conditions of the native (Ponto-Caspian) and introduced (Baltic) ranges of* D. villosus *are very similar to those of the Great Lakes.*
- *The Great Lakes and Ponto-Caspian region are "climatically compatible," which is one of the attributing factors to the success of Ponto-Caspian species in the Great Lakes (Reid and Orlova 2002).*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- Dikerogammarus villosus *inhabits fresh/brackish water, lakes, rivers, and canals in areas with low current velocity (Devin and Beisel 2006). It can adapt to a wide variety of substrates as well as a wide range of temperature, salinity, and oxygen levels.*
- Dikerogammarus villosus *is able to tolerate temperatures from 0-35°C, with an optimal temperature range of 5-15°C (Bruijs et al. 2001, Maazouzi et al. 2011, van der Velde et al. 2009, Wijnhoven et al. 2003). It can tolerate salinities ranging from 0 to 20 ppt (Bruijs et al. 2001, Grigorovich et al. 2003).*
- *Abiotic factors and climatic conditions of the native and introduced ranges of this species are quite similar to the Great Lakes, making the region compatible (Grigorovich et al. 2003, Reid and Orlova 2002).*
- *Great Lakes underwent similar anthropogenic eutrophication as the Ponto-Caspian region (Reid and Orlova 2002). Surface water temperature is similar between the Great Lakes and Ponto-Caspian seas (Grigorovich et al. 2003, Reid and Orlova 2002, USEPA 2008).*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3

Scarce (Suitable habitats are rarely found)	0
Unknown	U
	9

- *This species attaches itself to fastened banks, sheet-pile walls, and surface algae mats and can inhabit any substrate except sand (Crosier et al. 2011, Devin and Beisel 2006). It can also anchor itself within deep rock pools and under porous stones (Nesemann et al. 1995). In the lower Rhine, this species reaches its highest densities on hard substrates, primarily boulders, rocks, and pebbles within 3 meters of the shoreline (Kelleher et al. 1998, Platvoet et al. 2009). Different size classes of individuals tend to separate spatially, with the smallest individuals typically found on roots or macrophytes and larger individuals found in cobble (Mayer et al. 2008).*
- *The ability of* D. villosus *to occupy a range of habitats and wide environmental tolerances allows it to colonize the preferred habitats of both native and exotic species in Europe (Dick and Platvoet 2000).*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0
Unknown	U
	5

- *The suitable yearly breeding period is likely to be lengthened with warmer water temperatures, as has been observed with its relative* Dikerogammarus haemobaphes *(Kiticyna 1980).*
- *Although* D. villosus *has broad environmental tolerances, particularly with respect to high salinity, it is not known to survive in waters warmer than 35°C and may not typically survive prolonged exposure to temperatures in excess of 27°C (Bruijs et al. 2001, Maazouzi et al. 2011, van der Velde et al. 2009, Wijnhoven et al. 2003). However, this species prefers temperatures from 5 to 15°C and exhibits a limited potential to adjust to waters warmer than 20°C (Maazouzi et al. 2011).*

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is moderate to high)	3

Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
	9

- *Dikerogammarus villosus* is an omnivorous predator of many macroinvertebrates, including other gammarids, and is also able to collect detritus and to filter out suspended algae (Mayer et al. 2008). It exhibits a cannibalistic nature by occasionally eating conspecific newborns and weak adults (Devin and Beisel 2006, Dick and Platvoet 2000, Dick et al. 2002, Mordukhaĭ-Boltovskoĭ 1979a, Platvoet et al. 2009).

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Great Lakes and is not likely to be introduced	-80% total points (at end)
Unknown	U
	9

- *There is no critical species required by* D. villosus.

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes)	6
Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood	3

of encounter with this species assessed is hard to predict)	
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0
Unknown	U
	9

- *A strong ecological connection exists between* D. villosus *and other Great Lakes invaders from the Ponto-Caspian, such as* Dreissena polymorpha*; under the theory of "invasional meltdown," it has been predicted that invasion of the killer shrimp will be facilitated by these companion species (Devin et al. 2003, Dick and Platvoet 2000, Ricciardi and Rasmussen 1998). For instance, beds of* D. polymorpha *may facilitate establishment of this large amphipod by providing colonization substrate (Devin et al. 2003, Dick et al. 2002).*

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0
Unknown	U
	0

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9
Frequent, moderate inocula	6
Frequent, small inocula OR infrequent, large inocula	3
Infrequent, small or moderate inocula	0
Unknown	U
	U

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
	9

- *This species has been spreading rapidly since it began invading the Danube River in 1989. It has reached the Austro-German border, the Rhine estuary, and the Moselle River (Devin et al. 2001). It is also suspected to be the next successful invader of the Great Lakes (Bruijs et al. 2001, Ricciardi and Rasmussen 1998).*

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
	7

- *The dispersal rate of this species across Europe is similar to that of many other Ponto-Caspian invasive amphipods (e.g.,* Dikerogammarus haemobaphes*), spreading across the entire European continent in roughly 50 years (bij de Vaate et al. 2002).*

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing the establishment and spread of this species)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent the establishment and/or spread of this species	0

Unknown	U
	0

Establishment Potential Scorecard				
Points	**Probability for Establishment**	A. Total Points (pre-adjustment)		121
>100	High	**Adjustments**		
		B. Critical species	A*(1- 0%)	121
51-99	Moderate	C. Natural enemy	B*(1- 0%)	121
		Control measures	C*(1- 0%)	121
0-50	Low	**Potential for Establishment**		High
# of questions answered as "unable to determine"	**Confidence Level**			
0-1	High	Total # of questions unknown		1
2-5	Moderate			
6-9	Low	Confidence Level		High
>9	Very low			

Section C: Potential for Impact

IMPACT POTENTIAL RESULTS

Environmental: High

Socio-Economic: Low

Beneficial: Low

***Dikerogammarus villosus* has the potential for high environmental impact if introduced to the Great Lakes.**

Native to the lower Danube river system and Caspian Sea basin, *D. villosus* has recently invaded and spread throughout most of Western Europe, causing significant ecological disruption. *Dikerogammarus villosus* is a fierce predator and superior competitor. Its ability to eat and displace other amphipods has led to the prediction of a great reduction in amphipod diversity if introduced to a variety of North American freshwater habitats (Dick and Platvoet 2000). In the Netherlands, *D. villosus* has replaced many populations of the European native amphipod species *Gammarus duebeni*, as well as those of the North American invader *G. tigrinus* (Dick and Platvoet 2000). *Dikerogammarus villosus* has displaced an additional *Dikerogammarus* invader (*D. haemobaphes*) in portions of the Danube and Rhine rivers (Müller et al. 2002). This species also consumes eggs or juvenile stages of small fish, causing potential concern for game fish populations if introduced to the Great Lakes (Devin and Beisel 2006).

The short generation time, rapid growth rate, early sexual maturity, high fecundity, female-biased sex ratio, and large size of *D. villosus* as compared to related species make it a species expected to outcompete native species for resources (bij de Vaate et al. 2002). *Dikerogammarus villosus* also has been predicted to have serious direct and indirect negative environmental effects if introduced to the Great Lakes ecosystem (Dick et al. 2002).

Dikerogammarus villosus is host to several microsporidian parasites that may become emerging diseases in other crustaceans following host introduction (Bacela-Spychalska et al. 2012, Ovcharenko et al. 2010). Moreover, while many freshwater amphipods also serve as an intermediate host to acanthocephalan worms (parasites with birds and fish as final hosts), infection of *D. villosus* has not been confirmed (Médoc et al. 2006, in contrast to interpretation by Crosier et al. 2011 and others).

There is little or no evidence to support that *Dikerogammarus villosus* has the potential for significant socioeconomic impacts if introduced to the Great Lakes.

The socio-economic impact of this species on invaded areas of Western Europe is largely unknown. However, the ability of this species to consume eggs or juvenile stages of small fish creates a potential concern for fishery populations (Devin and Beisel 2006).

There is little or no evidence to support that *Dikerogammarus villosus* has the potential for significant beneficial effects if introduced to the Great Lakes.

Dikerogammarus villosus has displaced populations of other invading amphipods in Europe, including *D. haemobaphes* (another potential Great Lakes invader) (Müller et al. 2002).

POTENTIAL ENVIRONMENTAL IMPACT

NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1
Not significantly	0 √
Unknown	U

- Dikerogammarus villosus *is host to several microsporidian parasites that may become emerging diseases in other crustaceans following host introduction (Bacela-Spychalska et al. 2012, Ovcharenko et al. 2010).*
- *Moreover, while many freshwater amphipods also serve as an intermediate host to acanthocephalan worms (parasites with birds and fish as final hosts), infection of* D. villosus *has not been confirmed (Médoc et al. 2006, in contrast to interpretation by Crosier et al. 2011 and others).*

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1 √
Not significantly	0
Unknown	U

- *The short generation time, rapid growth rate, early sexual maturity, high fecundity, female-biased sex ratio, and large size of* D. villosus *as compared to related species make it a species expected to outcompete native species for resources (bij de Vaate et al. 2002).* Dikerogammarus villosus *also has been predicted to have serious direct and indirect negative environmental effects if introduced to the Great Lakes ecosystem (Dick et al. 2002).*

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in the food web)	6 √
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	1
Not significantly	0
Unknown	U

- Dikerogammarus villosus *is a fierce predator and superior competitor. Its ability to eat and displace other amphipods has led to the prediction of a great reduction in amphipod diversity if introduced to a variety of North American freshwater habitats (Dick and Platvoet 2000)*
- *In the Netherlands,* D. villosus *has replaced many populations of the European native amphipod species* Gammarus duebeni*, as well as those of the North American invader* G. tigrinus *(Dick and Platvoet 2000).* Dikerogammarus villosus *has displaced an additional* Dikerogammarus *invader (*D. haemobaphes*) in portions of the Danube and Rhine rivers (Müller et al. 2002).*
- *This species also consumes eggs or juvenile stages of small fish, causing potential concern for game fish populations if introduced to the Great Lakes (Devin and Beisel 2006).*

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6

Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0 √
Unknown	U

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1
Not significantly	0 √
Unknown	U

E6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1
Not significantly	0 √
Unknown	U

Environmental Impact Total	**7**
Total Unknowns (U)	**0**

Scoring		
Score	# U	**Impact**
>5	Any	**<u>High</u>**
2-5	Any	Moderate
0	0-1	Low
1	0	
0	≥2	Unknown
1	≥1	

POTENTIAL SOCIO-ECONOMIC IMPACT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1
Not significantly	0 √
Unknown	U

S2) Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1
Not significantly	0 √
Unknown	U

S3) Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0 √
Unknown	U

S4) Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0
Unknown	U √

- *The socio-economic impact of this species on invaded areas of Western Europe is largely unknown. However, the ability of this species to consume eggs and juvenile stages of small fish creates a potential concern for fishery populations (Devin and Beisel 2006).*

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

Socio-Economic Impact Total	**0**
Total Unknowns (U)	**1**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**Low**
1	0	
0	≥2	Unknown
1	≥1	

POTENTIAL BENEFICIAL EFFECT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular effect. An "Unknown" response is appropriate if the potential for a particular effect might be inferred but has not been explicitly reported or if there is an unresolved debate about a particular effect.

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1 √

Not significantly	0
Unknown	U

- Dikerogammarus villosus *has displaced populations of other invading amphipods in Europe, including* D. haemobaphes *(another potential Great Lakes invader) (Müller et al. 2002).*

B2) Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?

Yes, it is economically important to at least one of these industries	6
Yes, but its economic contribution is small	1
Not significantly	0 √
Unknown	U

B3) Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local communities and/or tourism	6
It is sometimes employed recreationally, but adds little value to local communities or tourism	1
Not significantly	0 √
Unknown	U

B4) Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR It is potentially important to medicine or research and is currently being or scheduled to be studied	1
Not significantly	0 √
Unknown	U

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1
Not significantly	0 √
Unknown	U

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1
Not significantly	0 √
Unknown	U

Beneficial Effect Total	**1**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**Low**
1	0	
0	≥2	Unknown
1	≥1	

Scientific Name: *Echinogammarus warpachowskyi*
G.O. Sars, 1894

Common Name: Scud

Synonyms:

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: Unlikely

Hitchhiking/fouling: Unlikely

Unauthorized intentional release: Unlikely

Stocking/planting/escape from recreational culture: Unlikely

Escape from commercial culture: Unlikely

Transoceanic shipping: Moderate

***Echinogammarus warpachowskyi* has a moderate probability of introduction to the Great Lakes (Confidence level: High).**

Potential pathway(s) of introduction: Transoceanic Shipping

Echinogammarus warpachowskyi has expanded its range from the Ponto-Caspian basin via human mediated vectors and is currently present in Northwest Russia, Gulf of Finland, as well as the Baltic Sea and its tributaries (Berezina 2007). This species occurs in ports that have direct trade connections with the Great Lakes (NBIC 2009).

Although *Echinogammarus warpachowskyi* posseses the ability to survive a wide range of salinities, it experiences partial mortality with exposure to full-strength seawater for 1 hour, and 100% mortality after 48 hours (Santagata et al. 2008).

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100
No, this species does not occur near waters connected to the Great Lakes basin and/or is not mobile or able to be transported by wind or water.	0 √
Unknown	U

- Echinogammarus warpachowskyi *is native to the Ponto-Caspian region, invasive throughout northwest Russia, as far as the Gulf of Finland, as well as the Baltic Sea and its tributaries (Berezina 2007).*

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0 √
Unknown	U

- Echinogammarus warpachowskyi *is native of the Ponto-Caspian region, invasive throughout Northwest Russia, as far as the Gulf of Finland, as well as the Baltic Sea and its tributaries (Berezina 2007).*

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a) Is this species sold at aquarium/pet/garden stores (“brick & mortar” or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100
No, this species this species is rarely/never sold.	0 √
Unknown	U

- Echinogammarus warpachowskyi *is not known to be sold.*

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0 √
Unknown	U

- Echinogammarus warpachowskyi *is not known to be stocked.*

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is likely to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces), this activity may occur within 20 km of the basin because of the species' popularity/value.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100
No, this species is not commercially cultured in or transported through the Great Lakes region.	0 √

Unknown	U

- Echinogammarus warpachowskyi *is not cultured or transported through the Great Lakes region.*

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80 √
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40
No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0
Unknown	U

- *This species is known to survive a wide range of salinity (0-20‰). However, with exposure to full-strength seawater,* E. warpachowskyi *will experience some mortality within an hour and 100% mortality within 48 hours (Santagata et al. 2008).*

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5 √
Yes, but this species has neither been observed in ballast/fouling ships entering the Great Lakes nor in ports in direct trade with the Great Lakes.	Score x 0.1

No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0
Unknown	U

- Echinogammarus warpachowskyi *is invasive throughout Northwest Russia, the Gulf of Finland, and the Baltic Sea and its tributaries (Berezina 2007).*

Vector Potential Scorecard				
Vector	**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind	**0**	x	**0**	Unlikely
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.	**0**	x	**0**	Unlikely
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)	**0**	x	**0**	Unlikely
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)	**0**	x	**0**	Unlikely
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)	**0**	x	**0**	Unlikely
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling	**80**	x 0.5	**40**	Moderate
Total Unknowns (U)	**0**	**Confidence Level**	High	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

ESTABLISHMENT POTENTIAL RESULTS

Status: **Not established in North America, including the Great Lakes**

***Echinogammarus warpachowskyi* has a moderate probability of establishment if introduced to the Great Lakes (Confidence level: High).**

The native and introduced ranges of *Echinogammarus warpachowskyi* have similar climate and abiotic conditions to that of the Great Lakes (Grigorovich et al. 2003, Reid and Orlova 2002, USEPA 2008). The Great Lakes has similar chlorophyll α concentrations as the Ponto-Caspian basin, which may facilitate *Echinogammarus warpachowskyi* establishment. With the progression of climate change, it is predicted that warmer waters and increased salinization of the Great Lakes will make it more similar to the conditions of the Ponto-Caspian (USEPA 2008). This species can tolerate mesotrophic and well-drained eutrophic lakes with high oxygen demands (Arbačiauskas 2005); it is likely to find a suitable habitat in the Great Lakes basin. This species is highly mobile, and may migrate to favorable conditions (Olenin and Leppäkoski 1999). *Echinogammarus warpachowskyi* may be capable of surviving low oxygen levels under the ice during the winters of the Great Lakes; it can tolerate dissolved oxygen levels as low as 0.308 mg/L (Arbačiauskas and Gumuliauskaité 2007). This species is omnivorous with shifting food strategies (Berezina 2007); *Echinogammarus warpachowskyi* is likely to find a food source in the Great Lakes. *Echinogammarus warpachowskyi* may be preyed on by fish in the Great Lakes, which may reduce its probability for establishment to some degree. It produces 2-3 broods each summer and the size of the brood is temperature dependent. The temperatures in the Great Lakes basin are slightly lower than the Ponto-Caspian region (USEPA 2008); broods of *Echinogammarus warpachowskyi* may be relatively smaller in the Great Lakes. However, warmer temperatures due to climate change may result in larger broods, aiding the establishment of this species. Historically, *Echinogammarus warpachowskyi* has spread locally from where it has been introduced (Arbačiauskas 2005). It is mobile (Olenin and Leppäkoski 1999).

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
	6

- Echinogammarus warpachowskyi *has high tolerances to salinity 0-20‰ (Berezina 2007, Grigorovich et al. 2003).* Echinogammarus warpachowskyi *can tolerate mesotrophic or well-drained eutrophic lakes, with high oxygen demands (Arbačiauskas 2005).*

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9
Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
	8

- Echinogammarus warpachowskyi *is mobile, can migrate, and may retreat to more favorable conditions (Berezina 2007).*
- *This species' lethal level of dissolved oxygen is 0.308 mg L^{-1} (Arbačiauskas and Gumuliauskaité 2007).*
- *This species originated in the Ponto-Caspian region, then spread within the Baltic and North Seas, so could likely withstand Great Lakes water temperatures (Grabowski et al. 2007a) .*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
	9

- Echinogammarus warpachowskyi *has an omnivorous diet with shifting/mixed food strategies (Berezina 2007, Berezina et al. 2011)*

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species	3

in the Great Lakes)	
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	0
Unknown	U
	6

- *With large* E. warpachowskyi *populations, native macroinvertebrates experience lower biodiversity and biomass,* Echinogammarus warpachowskyi *is likely to compete with other species (Arbačiauskas et al. 2010).* Echinogammarus warpachowskyi is o*mnivorous (Berezina 2007).*

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
	3

- Echinogammarus warpachowskyi *has 2-3 broods in summer months, the brood size being temperature dependent (Berezina 2007).*
- Echinogammarus ischnus *may produce 2 broods over the summer (Kley and Maier 2003, Kley and Maier 2006, Witt et al. 1997).*

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
	3

- *Variation from species to species varies greatly,* Echinogammarus warpachowskyi has *no species-specific information. However, the congeneric species* E. ischnus *has similar reproduction methods and has spread widely in the Great Lakes.*

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- Echinogammarus warpachowskyi *is native to the Ponto-Caspian region (Pinkster 1993).*
- *The Great Lakes and Ponto-Caspian region are "climatically compatible," which is one of the attributing factors to the success of Ponto-Caspian species in the Great Lakes (Reid and Orlova 2002).*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	7

- *Abiotic factors and climatic conditions of the native and introduced ranges of this species are quite similar to the Great Lakes, making the region compatible (Grigorovich et al. 2003, Reid and Orlova 2002).*
- *Great Lakes underwent similar anthropogenic eutrophication as the Ponto-Caspian region (Reid and Orlova 2002). Surface water temperature is similar between the Great Lakes and Ponto-Caspian seas (Grigorovich et al. 2003, Reid and Orlova 2002, USEPA 2008).*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0

Unknown	U
	9

- Echinogammarus warpachowskyi *is able to establish in mesotrophic or well-drained eutrophic lakes with a high turnover rate, and prefers the lower littoral zone; establishment improves as lake area increases (Arbačiauskas 2005).*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0
Unknown	U
	6

- *The brood size of* Echinogammarus warpachowskyi *increases with temperature (Berezina 2007).*
- *Furthermore, this species tolerates salinities of 0-20‰ and exhibits morphological changes in different habitats (Berezina 2007).*

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
	9

- Echinogammarus warpachowskyi *is omnivorous (Berezina 2007).*

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Great Lakes and is not likely to be introduced	-80% total points (at end)
Unknown	U
	9

- *No critical species to this species were found.*

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes)	6
Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0
Unknown	U
	0

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0
Unknown	U
	0

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9
Frequent, moderate inocula	6
Frequent, small inocula OR infrequent, large inocula	3
Infrequent, small or moderate inocula	0
Unknown	U
	U

- *Potential inoculum size and frequency are unknown.*
- *Intentional stocking of* Echinogammarus warpachowskyi *in Russia ended in the 1970s (Berezina 2007).*

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0

Unknown	U
	4

- *This species has been introduced from the Ponto-Caspian region to the Baltic and North Seas, where it has spread widely and rapidly (Grabowski et al. 2007b).*

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
	6

- *This species has been introduced from the Ponto-Caspian region to the Baltic and North Seas, where it has spread widely and rapidly (Grabowski et al. 2007b).*

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing the establishment and spread of this species)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent the establishment and/or spread of this species	0
Unknown	U
	0

Establishment Potential Scorecard				
Points	**Probability for Establishment**	A. Total Points (pre-adjustment)		93
>100	High	**Adjustments**		
		B. Critical species	A*(1- 0%)	93

51-99	Moderate	C. Natural enemy	B*(1- 0%)	93
		Control measures	C*(1- 0%)	93
0-50	Low	**Potential for Establishment**		Moderate
# of questions answered as "unable to determine"	**Confidence Level**			
0-1	High	Total # of questions unknown		1
2-5	Moderate			
6-9	Low	Confidence Level		High
>9	Very low			

Section C: Potential for Impact

IMPACT POTENTIAL RESULTS

Environmental: Moderate

Socio-Economic: Low

Beneficial: Moderate

***Echinogammarus warpachowskyi* has the potential for a moderate environmental impact if introduced to the Great Lakes.**

Establishment of *Echinogammarus warpachowskyi* in other areas resulted in a 2-fold decrease in community diversity (Arbačiauskas et al. 2010). Due to the high fitness of *Echinogammarus warpachowskyi*, there is an increase in its biomass where it has been established.

***Echinogammarus warpachowskyi* has the potential for low socio-economic impact if introduced to the Great Lakes.**

There is little or no evidence to support that *Echinogammarus warpachowskyi* has the potential for significant socio-economic impacts if introduced to the Great Lakes.

It has not been reported that *Echinogammarus warpachowskyi* poses a threat to human health or water quality. There is no evidence that this species negatively impacts infrastructure, economic sectors, recreational activities and associated tourism, or the aesthetic appeal of the areas it inhabits.

***Echinogammarus warpachowskyi* has the potential for moderate beneficial effects if introduced to the Great Lakes.**

Echinogammarus warpachowskyi has historically been used to increase the yields of certain types of fish (Berezina 2007). Establishment of *Echinogammarus warpachowskyi* may increase the production of perch in the Great Lakes.

POTENTIAL ENVIRONMENTAL IMPACT

NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1
Not significantly	0
Unknown	U √

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1 √
Not significantly	0
Unknown	U

- *The presence of this species has resulted in a two-fold decrease in community diversity, coupled with increased biomass (Arbačiauskas et al. 2010).* Echinogammarus warpachowskyi *is omnivorous (Berezina 2007) and produces up to three broods during summer months (Arbačiauskas 2002).*

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in the food web)	6
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	1 √
Not significantly	0
Unknown	U

- *There may be one to one replacement of native amphipods (Berezina 2007).*

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0
Unknown	U √

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1
Not significantly	0
Unknown	U √

E6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1
Not significantly	0
Unknown	U √

Environmental Impact Total	**2**
Total Unknowns (U)	**4**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	**Moderate**
0	0-1	Low

1	0	
0	≥2	Unknown
1	≥1	

POTENTIAL SOCIO-ECONOMIC IMPACT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1
Not significantly	0 √
Unknown	U

S2) Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1
Not significantly	0 √
Unknown	U

S3) Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0 √
Unknown	U

S4) Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0 √

Unknown	U

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

Socio-Economic Impact Total	**0**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**Low**
1	0	
0	≥2	Unknown
1	≥1	

POTENTIAL BENEFICIAL EFFECT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular effect. An "Unknown" response is appropriate if the potential for a particular effect might be inferred but has not been explicitly reported or if there is an unresolved debate about a particular effect.

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1
Not significantly	0 √
Unknown	U

B2) Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?

Yes, it is economically important to at least one of these industries	6
Yes, but its economic contribution is small	1 √
Not significantly	0
Unknown	U

- Echinogammarus warpachowskyi *is used in Russia to supplement fish food web to bolster fisheries (Berezina 2007).* Echinogammarus warpachowskyi *may have similar effectiveness in charter fishing industry for perch.*

B3) Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local communities and/or tourism	6
It is sometimes employed recreationally, but adds little value to local communities or tourism	1 √
Not significantly	0
Unknown	U

- Echinogammarus warpachowskyi *is used in Russia to supplement fish food web to bolster fisheries (Berezina 2007).* Echinogammarus warpachowskyi *may have similar effectiveness for perch.*

B4) Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR It is potentially important to medicine or research and is currently being or scheduled to be studied	1
Not significantly	0 √
Unknown	U

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1
Not significantly	0 √
Unknown	U

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1
Not significantly	0 √
Unknown	U

Beneficial Effect Total	**2**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	**<u>Moderate</u>**
0	0-1	Low
1	0	
0	≥2	Unknown
1	≥1	

Scientific Name: *Obesogammarus crassus*
G.O. Sars

Common Name: Scud

Synonyms: *Pontogammarus crassus*, *Niphargoides crassus*

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: Unlikely

Hitchhiking/fouling: Unlikely

Unauthorized intentional release: Unlikely

Stocking/planting/escape from recreational culture: Unlikely

Escape from commercial culture: Unlikely

Transoceanic shipping: Moderate

***Obesogammarus crassus* has a moderate probability of introduction to the Great Lakes (Confidence level: High).**

Potential Pathway(s): Transoceanic Shipping

Currently, this species has not been found near waters connected to the Great Lakes, although it occurs in waters that have direct trade connections with the Great Lakes, such as the Baltic Sea (Sala et al. 2000, NBIC 2009). Ballast water may be a potential vector for the introduction of *Obesogammarus crassus* (Ricciardi and Rasmussen 1998). It should be noted that where *Obesogammarus crassus* is introduced, it is frequently inoculated in high numbers by ballast water exchange (Grabowski et al. 2007b). The distribution of this species has already spread extensively beyond its native range; it has been introduced to western European waters via ballast water transport (Holdrich and Pöckl 2007). However, *Obesogarmmarus crassus* experiences complete mortality under flow through, full strength seawater for 24 hours (Santagata et al. 2008).

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100
No, this species does not occur near waters connected to the Great Lakes basin and/or is not mobile or able to be transported by wind or water.	0 √
Unknown	U

- Obesogammarus crassus *is a Ponto-Caspian species and has recently been found in the Curonian and Vistula Lagoon on the Russian part of the Baltic Sea (Berezina et al. 2011). This species does not occur near waters connected to the Great Lakes.*

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0 √
Unknown	U

- Obesogammarus crassus *is not known to be able to attach or be transported by recreational gear, trailers, fauna, or flora.*

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a) Is this species sold at aquarium/pet/garden stores (“brick & mortar” or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100
No, this species this species is rarely/never sold.	0 √

Unknown	U

- Obesogammarus crassus *is not known to be sold at aquarium/pet/garden stores or purchased for human consumption, ornamental, ethical, or cultural reasons.*

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0 √
Unknown	U

- *Although stocking is one of the vectors of introduction of* Obesogammarus crassus *(Olenin et al. 2010), it is currently in the Baltic Sea so there is not enough interest to stock this species in the Great Lakes region, or at least it is not known to be stocked in the Great Lakes region at present.*

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is likely to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces), this activity may occur within 20 km of the basin because of the species' popularity/value.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes	100

region.	
No, this species is not commercially cultured in or transported through the Great Lakes region.	0 √
Unknown	U

- Obesogammarus crassus *is not known to be commercially cultured in or transported through the Great Lakes region.*
- *Whether* Obesogammarus crassus *is commercially cultured near the Baltic sea is unknown.*

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80 √
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40
No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0
Unknown	U

- *Ballast water has been identified as a vector of introduction of* Obesogammarus crassus *to the Great Lakes (Ricciardi and Rasmussen 1998).* Obesogammarus crassus *is also known to survive extreme temperatures and absence of light.*
- Obesogammarus crassus *is a euryhaline species (Ricciardi and Rasmussen 1998).*
- Obesogammarus crassus *is eurythermic and able to tolerate temperatures up to 30°C, although the optimal temperature for reproduction maybe lower (Olenin 2011).*
- *This species is recorded as being introduced to western European waters through ballast water transport (Holdich and Pöckl 2007).*

- *Experimental data suggests that* O. crassus *may experience 100% mortality after 3 hours with empty-refill ballast water exchange and after 24 hours with flow-through exchange with full strength seawater (Santagata et al. 2008).*

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5 √
Yes, but this species has neither been observed in ballast/fouling ships entering the Great Lakes nor in ports in direct trade with the Great Lakes.	Score x 0.1
No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0
Unknown	U

- Obesogammarus crassus *occurs in waters from which shipping traffic to the Great Lakes originates (Sala et al. 2000), including the Baltic Sea.*

Vector Potential Scorecard				
Vector	**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind	**0**	x	**0**	Unlikely
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.	**0**	x	**0**	Unlikely
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)	**0**	x	**0**	Unlikely
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)	**0**	x	**0**	Unlikely
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)	**0**	x	**0**	Unlikely
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling	**80**	x 0.5	**40**	Moderate
Total Unknowns (U) **0**		**Confidence Level**	High	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

ESTABLISHMENT POTENTIAL RESULTS

Status: **Not established in North America, including the Great Lakes**

***Obesogammarus crassus* has a high probability of establishment if introduced to the Great Lakes (Confidence level: Moderate).**

The climatic conditions in the Ponto-Caspian and Baltic Sea are very similar to those in the Great Lakes. If *Obesogammarus crassus* is introduced, it can tolerate wide ranges of salinity and temperature. *Obesogammarus crassus* is eurythermic; able to tolerate temperatures up to 30°C (Olenin 2011). It can tolerate salinities from 0 to 20 psu (Santagata et al. 2008) and poorly oxygenated water about <2 mg/l O2 (Olenin 2011). *Obesogammarus crassus* is an omnivore (Hänfling et al. 2011), meaning, it will find the available nutritive foods easily in the Great Lakes. It has non-specific food preference (bij de Vaate et al. 2002) and, thus, *O. crassus* is dietary generalist with a broad, assorted, and flexible diet. O. crassus has outcompeted various native species in the introduced area and has a high fecundity (bij de Vaate et al. 2002).

O. crassus is inoculated in high numbers and very frequently by ballast water exchange (Grabowski et al. 2007b). This species has spread very extensively outside of its native range. *O. crassus* is known to spread from Lithuania in the Neman River to Curonian lagoon to Vistula lagoon to Oder Lagoon to Elbe River and now to Baltic Sea within ~50 years (bij de Vaate et al. 2002). However, due to ballast water management, the probability of establishment in the Great Lakes is low.

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other	6

factors is narrower, unknown, or unreported.	
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
	9

- Obesogammarus crassus *has salinity tolerance of 0 to 20 psu (Santagata et al. 2008).* Obesogammarus crassus *is found in littoral zone of the Vistula lagoon and of the Dead Vistula, both brackish with salinities between 1-6 psu, thus the presence of this species would only occur in oligohaline water bodies (Grabowski et al. 2007b).*
- Obesogammarus crassus *can tolerate both fresh waters and brackish waters (Jażdżewski et al. 2004).*
- *Broad diet, high genetic variability, and tolerance of a fairly broad range of salinity, temperature and oxygen concentration has led to successful invasion and rapid increase in new habitats by this species (Surowiec and Dobrzycka-Krahel 2008)*
- Obesogammarus crassus *is eurythermic; able to tolerate temperatures up to 30°C, although the optimal temperature for reproduction maybe lower (Olenin 2011).*
- Obesogammarus crassus *can handle poorly oxygenated water about <2 mg/l O2 (Olenin 2011).*
- Obesogammarus crassus *is a euryoecious species; it can survive in a broad range of ecological living conditions (bij de Vaate et al. 2002).*

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9
Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
	9

- Obesogammarus crassus *can survive extremely low levels of oxygen, light, and temperature in the Great Lakes.*
- Obesogammarus crassus *can handle poorly oxygenated water about <2 mg/l O2 (Olenin 2011)*
- Obesogammarus crassus *is a euryoecious species; it can survive in a broad range of ecological living conditions (bij de Vaate et al. 2002).*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
	9

- Obesogammarus crassus *has a non-specific food preference (bij de Vaate et al. 2002); this species is an omnivore (Hänfling et al. 2011).*

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	0
Unknown	U
	9

- *In the Curonian Lagoon*, O. crassus *has caused a severe reduction of the relative abundance of the former community dominant species or even population extinction within the ecosystem (*Zaiko et al. 2010).
- *The most visible change In the Vistula Lagoon is the increasing dominance of* O. crassus *(Grabowski et al. 2006).*
- *Based on the evidence presented in the above areas, this species is likely to outcompete species in the Great Lakes for available resources.*

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
	3

- *One of the most fecund amphipods as reported (Grabowski et al. 2007b) is* P. robustoides. *The partial fecundity of* P. robustoides *is 5.10, while the partial fecundity of* O. crassus *and* G roeselii *is 2.87 and 0.87, respectively (Grabowski et al. 2007b). The fecundity of* O. crassus *is intermediated compared to other amphipods.*
- Obesogammarus crassus *does not have high fecundity (bij de Vaate et al. 2002).*

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment	9

in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
	4

- *The female carries the eggs in a brood pouch, the mean brood size being 25.33.* O. crassus *has an average of 3 generations per year (Grabowski et al. 2007b).*
- Obesogammarus crassus *has a relatively short life span and generation time and does not have rapid growth nor early sexual maturity (bij de Vaate et al. 2002).*

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- *The climatic conditions in the native area, Ponto-Caspian, and introduced area, Baltic Sea, are similar to those in the Great Lakes region.*
- *The Great Lakes and Ponto-Caspian region are climatically compatible, which is one of the attributing factors to the success of Ponto-Caspian species in the Great Lakes (Reid and Orlova 2002).*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0

Unknown	U
	8

- *The salinity in the native range is 0 to 18 psu (Paavola et al. 2005), and* O. crassus *has a tolerance of 0 to 20 psu (Santagata et al. 2008), thus, it can easily find suitable habitats in fresh waters of Great Lakes.*
- Obesogammarus crassus *is eurythermic; able to tolerate temperatures up to 30°C, although the optimal temperature for reproduction maybe lower (Olenin 2011).*
- *No reports have been found on the pollution, nutrient levels, or currents.*
- *Abiotic factors and climatic conditions of the native and introduced ranges of this species are quite similar to the Great Lakes, making the region compatible (Grigorovich et al. 2003, Reid and Orlova 2002).*
- *Great Lakes underwent similar anthropogenic eutrophication as the Ponto-Caspian region (Reid and Orlova 2002). Surface water temperature is similar between the Great Lakes and Ponto-Caspian seas (Grigorovich et al. 2003, Reid and Orlova 2002, USEPA 2008).*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0
Unknown	U
	9

- *The native habitats of* O. crassus *is limnetic (Olenin et al. 2010), however,* O. crassus *is classified as nekto-benthic ecofunctional group of invertebrates (Olenin et al. 2010). Thus, it has been found in both the benthic and limnetic zones.* O. crassus *can find suitable habitats in the Great Lakes.*
- Obesogammarus crassus *has been found in both fresh waters and brackish waters (Grabowski et al. 2007b).*
- Obesogammarus crassus *can handle poorly oxygenated water about <2 mg/l O2 (Olenin 2011).*
- Obesogammarus crassus *is a euryoecious species; it can survive in a broad range of ecological living conditions (bij de Vaate et al. 2002).*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0

Unknown	U
	9

- Obesogammarus crassus *is likely to adapt to warmer water temperatures, shorter duration of ice cover, and increases salinization due to its wide environment tolerances.*
- Obesogammarus crassus *has salinity tolerance of 0 to 20 psu (Santagata et al. 2008).*
- Obesogammarus crassus *is eurythermic; able to tolerate temperatures up to 30°C, although the optimal temperature for reproduction maybe lower (Olenin et al 2010).*

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
	9

- Obesogammarus crassus *has a non-specific food preference (bij de Vaate et al. 2002); this species is an omnivore (Hänfling et al. 2011).*
- Obesogammarus crassus *is a dietary generalist with a broad, assorted, and flexible diet, therefore, O. crassus is likely to find an appropriate food source including, species in the Great Lakes that may be considered potential food items.*

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in	-80% total

the Great Lakes and is not likely to be introduced	points (at end)
Unknown	U
	9

- *There has been no report of critical species being required by* O. crassus *during any of the stages of its life cycle, therefore, it can be concluded that* O. crassus *does not require any other species.*

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes)	6
Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0
Unknown	U
	U

- *There has been no report of the establishment of* O. crassus *to be aided by the establishment and spread of another species already in the Great Lakes, therefore, it is unknown.*

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0
Unknown	U
	U

- *There is no report of natural enemy of* O. crassus *in the literature, therefore, it is unknown.*

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9
Frequent, moderate inocula	6
Frequent, small inocula OR infrequent, large inocula	3
Infrequent, small or moderate inocula	0
Unknown	U
	U

- *Ballast water transport allows for the introduction of* O. crassus *at distant places. Ballast water exchange creates a high propagule pressure at the points of discharge (Hänfling et al. 2011).*
- *According to the reports from 1993 and 1996, the world's major cargo vessels transfer 8–10 billion tons of ballast water per year, and that on average 3000 to 4000 species are transported by ships each day (Grabowski et al. 2007b).*
- *The frequency of* O. crassus *in ballast tanks is unknown.*

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
	8

- Obesogammarus crassus *is a Ponto-Caspian species that has been found in Curonian lagoon and Vistula lagoon (Berezina et al. 2011), in Szczecin lagoon and Elbe river in Germany (Grabowski et al. 2007b). It has spread from Caspian Sea to Black Sea and Baltic Sea areas.*
- *The central corridor of dispersal covers the route Dnieper River → Vistula River → Oder River → Elbe River → Rhine River, and from there,* O. crassus *was able to reach the Baltic Sea and western Europe (bij de Vaate et al. 2002).*
- Obesogammarus crassus *has very extensively spread in many areas.*

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
	5

- Obesogammarus crassus *has very extensively spread in wide ranges of areas.*
- Obesogammarus crassus *is known to spread from Lithuania in the Neman River to Curonian lagoon to Vistula lagoon to Oder Lagoon to Elbe River and now to Baltic Sea within ~50 years (bij de Vaate et al. 2002).*

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing the establishment and spread of this species)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent the establishment and/or spread of this species	0
Unknown	U
	0

Establishment Potential Scorecard				
Points	**Probability for Establishment**	A. Total Points (pre-adjustment)		108
>100	High	**Adjustments**		
		B. Critical species	A*(1- 0%)	108
51-99	Moderate	C. Natural enemy	B*(1- 0%)	108
		Control measures	C*(1- 0%)	108
0-50	Low	**Potential for Establishment**		High
# of questions answered as	**Confidence**			

"unable to determine"	Level		
0-1	High	Total # of questions unknown	3
2-5	Moderate		
6-9	Low	Confidence Level	Moderate
>9	Very low		

Section C: Potential for Impact

IMPACT POTENTIAL RESULTS

Environmental: High

Socio-Economic: Low

Beneficial: Low

***Obesogammarus crassus* has the potential for high environmental impact if introduced to the Great Lakes.**

The presence of *Obesogammarus crassus*, *Pontogammarus robustoides*, and *Dreissena polymorpha* in the Curonian Lagoon resulted in a severe reduction in the relative abundance of the former community and even population extinction within the ecosystem (Zaiko et al. 2011). However, the species identity of the populations that faced extinction is unknown. Whether the introduction of *Obesogammarus crassus* alone caused the reduction in the relative abundance of the former community is not specified. Where it is introduced, there is a significant reduction in native species, especially in the Curonian Lagoon (Zaiko et al. 2011). The relative abundance of the species that dominated the former community was significantly reduced. The populations of certain species faced extinction within this particular community. In the lower and upper reaches of the Pripyat River, *Obesogammarus crassus* comprises 80% of the total species abundance (Semenchenko and Vezhnovetz 2008).

There is little or no evidence to support that *Obesogammarus crassus* has the potential for significant socio-economic impacts if introduced in the Great Lakes.

Establishment of *Obesogammarus crassus* has not been known to cause a hazard or threat to human health, damage to infrastructure, or negative impacts on water quality. It has not been documented that this species is detrimental to markets or economic sectors, recreational activities or associated tourism, or the perceived aesthetic or natural value of the areas it inhabits.

There is little or no evidence to support that *Obesogammarus crassus* has the potential for significant beneficial effects if introduced in the Great Lakes.

It is stocked in some areas, but there are no reports concluding that it is commercially valuable.

POTENTIAL ENVIRONMENTAL IMPACT

NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1
Not significantly	0 √
Unknown	U

- Obesogammarus crassus *does not carry any microparasites (Ovcharenko et al. 2010).*
- Obesogammarus crassus *is not known to be poisonous.*

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6 √
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1
Not significantly	0
Unknown	U

- *In the Curonian lagoon,* O. crassus *have caused a severe reduction of the relative abundance of the former community dominant species or even population extinction within the ecosystem (Zaiko et al. 2010).*
- *In the middle and lower parts of Pripyat river, the abundance of* O. crassus *is more higher and equal 80% from total abundance of other amphipods (Semenchenko and Vezhnovetz 2008).*

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in the food web)	6
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	1
Not significantly	0
Unknown	U √

- *In the Curonian lagoon,* O. crassus *have caused a severe reduction of the relative abundance of the former community dominant species or even population extinction within the ecosystem" (Zaiko et al. 2010). However, it is unknown whether this is caused by predation.*

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0 √
Unknown	U

- *There have been no reports of* O. crassus *affecting any native populations genetically*.

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1
Not significantly	0 √
Unknown	U

- *There have been no reports of* O. crassus *negatively affecting water quality.*

E6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1
Not significantly	0 √
Unknown	U

- O. crassus *is not known to alter physical components of the ecosystem in some way.*

Environmental Impact Total	**6**
Total Unknowns (U)	**1**

Scoring		
Score	# U	**Impact**
>5	Any	**<u>High</u>**
2-5	Any	Moderate
0	0-1	Low
1	0	
0	≥2	Unknown
1	≥1	

POTENTIAL SOCIO-ECONOMIC IMPACT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1
Not significantly	0 √
Unknown	U

- *There have been no reports of* O. crassus *posing hazard or threat to human health.*

S2) Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1
Not significantly	0 √
Unknown	U

- *There have been no reports of* O. crassus *causing damage to infrastructure.*

S3) Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0 √
Unknown	U

- *There have been no reports of* O. crassus *negatively affecting water quality.*

S4) Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

- *There have been no reports of* O. crassus *negatively affecting any markets or economic sectors.*

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

- *There have been no reports of* O. crassus *inhibiting recreational activities and/or associated tourism.*

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

- Obesogammarus crassus *has not been known to diminish the perceived aesthetic or natural value of the areas it inhabits.*

Socio-Economic Impact Total	**0**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**Low**
1	0	

0	≥2	Unknown
1	≥1	

POTENTIAL BENEFICIAL EFFECT

NOTE: In this section, a “Not significantly” response should be selected if there have been no reports of a particular effect. An “Unknown” response is appropriate if the potential for a particular effect might be inferred but has not been explicitly reported or if there is an unresolved debate about a particular effect.

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1
Not significantly	0 √
Unknown	U

- Obesogammarus crassus *is not known to act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms.*

B2) Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?

Yes, it is economically important to at least one of these industries	6
Yes, but its economic contribution is small	1
Not significantly	0 √
Unknown	U

B3) Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local communities and/or tourism	6
It is sometimes employed recreationally, but adds little value to local communities or tourism	1
Not significantly	0 √
Unknown	U

B4) Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR	1

It is potentially important to medicine or research and is currently being or scheduled to be studied	
Not significantly	0 √
Unknown	U

- Obesogammarus crassus *is not known to have any medicinal or research value.*

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1
Not significantly	0 √
Unknown	U

- Obesogammarus crassus *is not known to remove toxins or pollutants from the water of otherwise increase water quality.*

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1
Not significantly	0 √
Unknown	U

- *O. crassus is not known to have any positive ecological impact outside of biological control.*

Beneficial Effect Total	**0**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**Low**
1	0	**Low**
0	≥2	Unknown
1	≥1	Unknown

Scientific Name: ***Obesogammarus obesus***
G.O. Sars, 1894

Common Name: Scud

Synonyms: *Pontogammarus obesus, Gammarus obesus*

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: Unlikely

Hitchhiking/fouling: Unlikely

Unauthorized intentional release: Unlikely

Stocking/planting/escape from recreational culture: Unlikely

Escape from commercial culture: Unlikely

Transoceanic shipping: Low

***Obesogammarus obesus* has a low probability of introduction to the Great Lakes (Confidence level: High).**

Potential pathway(s) of introduction: Transoceanic Shipping

From its native range, *Obesogammarus obesus* was introduced to Germany through ballast water and sediment, and to Austria via floating structures, ballast water, and sediments (NOBANIS 2014, DAISIE 2008b). Cooling water systems of ships may also be a vector for introduction of *Obesogammarus obesus* (Tittizer and Banning 2000). Currently, *Obesogammarus obesus* does not occur near waters connected to the Great Lakes basin. *Obesogammarus obesus* occurs within a major shipping route in Europe (Locke et al. 1993, Mills et al. 1993). It does not currently occur in a port that is in direct trade with the Great Lakes, it is spreading in that direction (Nehring 2006). *Obesogammarus obesus* is capable of surviving oceanic transport (Ricciardi and Rasmussen 1998). *Obesogammarus obesus* can tolerate salinities between 0.1 – 20 ppm (Berezina 2007, bij de Vaate et al. 2002). It does not produce resistant resting egg stages; ballast water exchange and flushing may limit egg transport and survival (Grigorovich et al. 2003).

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100

No, this species does not occur near waters connected to the Great Lakes basin and/or is not mobile or able to be transported by wind or water.	0 √
Unknown	U

- Obesogammarus obesus *is a Ponto-Caspian amphipod that has spread through the Danube River to the Rhine River (Nehring 2006).*

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0 √
Unknown	U

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a) Is this species sold at aquarium/pet/garden stores (“brick & mortar” or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100
No, this species this species is rarely/never sold.	0 √

Unknown	U

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1
Unknown	U

<u>POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE</u>

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0 √
Unknown	U

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is <u>likely</u> to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces), this activity <u>may</u> occur within 20 km of the basin because of the species' popularity/value.	Score x 0.25
Unknown	U

<u>POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE</u>

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100
No, this species is not commercially cultured in or transported through the Great Lakes region.	0 √
Unknown	U

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80 √
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40
No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0
Unknown	U

- Obesogammarus obesus *is a euryhaline species (bij de Vaate et al. 2002).*
- *The survival of amphipods during transportation in ballast tanks (water or sediments) is possible in most cases because of the high tolerance of this group of animals to different abiotic factors, mainly salinity, surviving 0.1-20 ppm (Berezina 2007).*
- Obesogammarus obesus *is not likely to survive ballast water exchange (no resistant adult or resting stages) (Grigorovich et al. 2003).*
- Obesogammarus obesus *can survive oceanic transport (Ricciardi 1998).*
- Obesogammarus obesus *has been introduced via ballast water and sediments to Germany (NOBANIS 2014); Austria via floating structures, ballast water and/or sediments in tanks (DAISIE 2008b).*
- *Other vector includes cooling water systems of ships (Tittizer and Banning 2000).*

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1

Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5
Yes, but this species has neither been observed in ballast/fouling ships entering the Great Lakes nor in ports in direct trade with the Great Lakes.	Score x 0.1 √
No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0
Unknown	U

- *This species is present within a major shipping route in Europe (Locke et al. 1993, Mills et al. 1993), and while not yet in a port, such as the lower Rhine River and Baltic Sea, with direct trade between Great Lakes and Ponto-Caspian, it continues to spread in that direction (Nehring 2006).*

Vector Potential Scorecard				
Vector	**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind	**0**	x	**0**	Unlikely
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.	**0**	x	**0**	Unlikely
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)	**0**	x	**0**	Unlikely
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)	**0**	x	**0**	Unlikely
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)	**0**	x	**0**	Unlikely
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling	**80**	x 0.1	**10**	Low
Total Unknowns (U)	**0**	**Confidence Level**	High	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High

1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

ESTABLISHMENT POTENTIAL RESULTS

Status: **Not established in North America, including the Great Lakes**

***Obesogammarus obesus* has a high probability of establishment if introduced to the Great Lakes (Confidence level: high).**

The native and introduced ranges of *Obesogammarus obesus* have similar climate and abiotic conditions to that of the Great Lakes (Grigorovich et al. 2003, Reid and Orlova 2002, USEPA 2008). This species occurs in Belarus, which is located in similar latitudes as the Great Lakes basin (Semenchenko and Vezhnovetz 2008). The level of light penetration in the Black Sea is similar to that of the Great Lakes basin (Ojaveer et al. 2002). The primary productivity of the Black Sea (150 - 200 g C m^{-2} yr^{-1}) is similar to that of the Great Lakes (100 – 310 g C m^{-2} yr^{-1}). This species can tolerate and adapt to a variety of environmental conditions and habitats (Bacela and Konopacka 2005, Mordukhaĭ-Boltovskoĭ 1960, Mordukhaĭ-Boltovskoĭ and Chirkova 1971, Pjatakova and Tarasov 1996). It is able to avoid unsuitable conditions and migrate to locate more suitable habitats (Berezina 2007). It can tolerate salinities from 0.1 – 20 ppm (bij de Vaate et al. 2002, Berezina 2007). It is likely that *Obesogammarus obesus* can overwinter in the Great Lakes; it occurs in waters that have low temperatures and ice cover (Reid and Orlova 2002). Climate change may facilitate the establishment of this species in the Great Lakes basin; it occurs in areas that are warmer than the Great Lakes and is capable of surviving in higher salinities.

Obesogammarus obesus is a dietary generalist (bij de Vaate et al. 2002, Elexová and Némethová 2003); it is likely that the Great Lakes contain an abundant food source for this species. This species is a significant portion of the diet of round gobies, which are nonindigenous fish established in the Great Lakes basin; however, predation by these fish has not prevented the establishment of other amphipods to the Great Lakes such as *Echinogammarus ischnus* and *Gammarus tigrinis*, nor the establishment of *Obesogammarus obesus* where it has been introduced beyond its native range (Borza et al. 2009). The short generation time of *Obesogammarus obesus* may facilitate its establishment (bij de Vaate et al. 2002). Dreissenid mussels, which are already established in the Great Lakes, may aid the establishment of *Obesogammarus* obesus; evidence suggests there is a positive relationship between the density of *Obesogammarus obesus* and the biomass of dreissenid mussels (Alexander Protasov pers comm). A closely related scud species, *Echinogammarus ischnus*, has a greater dominance over native *Gammarus fasciatus* in dreissenid beds (Dermott et al. 1998).

In the upper reaches of impoundments of the Danube River, Germany, *Obesogammarus obesus* attained densities up to 3,300 individuals/m^2, which was associated with a displacement of several other amphipod species such as *Dikerogammarus* species. *Obesogammarus obesus* reaches high densities that are greater than or similar to the densities of the serious invaders or dominant species in the community (Žganec et al. 2009). This species is capable of migrating and dispersing with an average rate of 130km/year (Leuven et al. 2009). *Obesogammarus obesus* has immigrated over 4,000 km from their native area to the middle part of the Volga River (Lyakhov 1961, Mordukhaĭ-Boltovskoĭ 1960).

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
	8

- *It would be described as euryocious, euryhaline (bij de Vaate et al. 2002).*
- Obesogammarus obesus *can adapt to new habitats, morphological and physiological adaptation (Dedyu 1967, Mordukhaĭ-Boltovskoĭ 1960, Mordukhaĭ-Boltovskoĭ and Chirkova 1971).*
- Obesogammarus obesus *can migrate to find suitable conditions (Berezina 2007).*
- Obesogammarus obesus *is most characteristic for the potamon (lower part of a river in which the water is typically slow-moving, still-surfaced, deep, and relatively warm, favouring limnophilous, stenothermous organisms that are thrifty in their use of dissolved oxygen) (Nesemann et al. 1996).*
- Obesogammarus obesus *may be able to adapt to different environmental conditions (Pjatakova and Tarasov 1996).*

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9
Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
	8

- Obesogammarus obesus *occurs in Belarus, which is located at 52-56°N (Great Lakes at 41-49°N) (Semenchenko and Vezhnovetz 2008).*
- Obesogammarus obesus *can adapt to and/or avoid unsuitable conditions (Dedyu 1967, Mordukhaĭ-Boltovskoĭ 1960,, Mordukhaĭ-Boltovskoĭ and Chirkova 1971).*
- *Water surface temperatures in Black sea reach -0.5°C in winter, to 23-26°C in summer (Encyclopedia Brittanica 2015).*
- *Due to the climatic similarities between the Great Lakes and Ponto-Caspian regions (Reid and Orlova 2002).* O. obesus *most likely endures similar overwintering conditions in its native range.*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
	9

- Obesogammarus obesus *have nonspecific food preference (bij de Vaate et al. 2002).*
- Obesogammarus obesus are *generalist: 20% Shredder, 10% Scraper, 20% Collector of fine organic material, 30% Predator) (Elexová and Némethová 2003).*

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	0
Unknown	U
	9

- Obesogammarus obesus *can attain densities of up to 3,300 individuals/m² in the upper reaches of impoundments of the navigable section of the Danube River in German which are characterized by widespread silt deposits (Tittizer et al. 2000). These high abundances of* O. obesus *were associated with a displacement of several other amphipod species (i.e., Dikerogammarus spp.) (Tittizer et al. 2000).*
- *While no studies in the Great Lakes, it has been found to be more numerous than many serious invaders like* Dikerogammarus villosus *(Žganec et al. 2009) or with abundances just below species abundant in the Great Lakes (e.g., E. ishnus) (Pockl 1994 pers comm. in Holdich and Pöckl 2007).*
- Obesogammarus obesus *was found to be highly abundant in several areas (40-100%) (Elexová and Némethová 2003, Bódis et al. 2012).*
- Obesogammarus obesus *dominates periphyton in shallow depths (Protasov and Silaeva 2010).*

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9

High	6
Moderate	3
Low	0
Unknown	U
	U

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
	6

- *This species broods its young and protects its juveniles (bij de Vaate et al. 2002).*
- Obesogammarus obesus *has a relatively short generation time (bij de Vaate et al. 2002).*

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- *The Great Lakes and the Black Sea (where present) are very similar: latitude 41-49°N and 41-46°N, respectively. While the climate around the Black Sea varies, it is generally continental (pronounced seasonal variations). Northwestern Black Sea seas have ice formation. Mean temperature over central portion of the sea is 8°C, over western portion 2-3°C in January; spring about 16°C, summer about 24°C. Extremes of -30°C to 37°C (Encyclopedia Britanica 2015).*

- *While precipitation varies by region/city, many are very similar to a Great Lakes city (e.g., Istanbul and Detroit at 850mm).*
- *The Great Lakes and Ponto-Caspian region are climatically compatible, which is one of the attributing factors to the success of Ponto-Caspian species in the Great Lakes (Reid and Orlova 2002).*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	7

- *Primary production for Black Sea ranges from 150-200 C m-2 yr-1, and the Great Lakes range from 100-310g C m-2 yr-1 (Ojaveer et al. 2002). O. obesus found in many freshwater habitats, as in the Great Lakes region.*
- Obesogammarus obesus *is most characteristic of the potamon (which prefers slow-moving, still-sufaced deep waters); found in lower and middle reaches of rivers as well as Black Sea and dam lakes (Nehring 2006).*
- *Abiotic factors and climatic conditions of the native and introduced ranges of* O. obesus *are quite similar to the Great Lakes, making the region compatible (Reid and Orlova 2002, Grigorovich et al. 2003).*
- *Great Lakes underwent similar anthropogenic eutrophication as the Ponto-Caspian region (Reid and Orlova 2002). Surface water temperature is similar between the Great Lakes and Ponto-Caspian seas (Grigorovich et al. 2003, Reid and Orlova 2002, USEPA 2008).*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0
Unknown	U
	8

- *Sunlight (water transparency in meters) similar between Lake Erie and Black Sea (>8m) is suitable (Ojaveer et al. 2002).*
- Obesogammarus obesus *migrates between deep and shallow waters to find ideal conditions (Berezina 2007).*
- Obesogammarus obesus is *found in gravel, gravel-sand, sand/mud (Borza et al. 2009, Nesemann et al. 1996, Elexová and Némethová 2003, Nehring 2006).*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0
Unknown	U
	9

- Obesogammarus obesus *lives in areas warmer than the Great Lakes (southern Black Sea and inland Europe), many without any ice cover year-round. The can migrate to find better conditions, and do well in high salinities (potentially outcompete natives).*

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
	9

- Obesogammarus obesus *have nonspecific food preference (bij de Vaate et al. 2002).*
- Obesogammarus obesus are *generalist: 20% Shredder, 10% Scraper, 20% Collector of fine organic material, 30% Predator) (Elexová and Némethová 2003).*

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being	9

assessed; OR, No, there is no critical species required by the species being assessed	
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Great Lakes and is not likely to be introduced	-80% total points (at end)
Unknown	U
	9

- *No, there is no critical species required*

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes)	6
Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0
Unknown	U
	7

- *A positive relationship between number of* O. obesus *(ind/m^2) and dreissenid biomass (g/m^2) has been found (R^2=0.347) (Alexander Protasov pers comm.).*
- *Also seen in related species present in the Great Lakes: the Great Lakes invader (and a similar species found in similar areas)* E. ischnus *may have benefited from a co-evolved relationship with dreissenid mussels (e.g., greater dominance over native G. fasciatus in dreissenid beds) (Ricciardi and MacIsaac 2000).*

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0
Unknown	U
	-10%

- Obesogammarus obesus i*s a significant portion of round and bighead goby diet (Borza et al. 2009), however, similar predation has not prevented establishment of other amphipods into the Great Lakes (e.g.,* E. ischnus *and* G. tigrinis*) nor introduction and dominance of* O. obesus *in other invaded ranges.*

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9
Frequent, moderate inocula	6
Frequent, small inocula OR infrequent, large inocula	3
Infrequent, small or moderate inocula	0
Unknown	U
	2

- *Ballast Water Exchange would eliminate most individuals of this species from ballast tanks, but given the frequency of travel of ships between Great Lakes and Europe, inoculation could be frequent.*

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3

Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
	8

- Obesogammarus obesus *reached the middle part of the Volga River spreading upstream more than 4,000 km from their native area (Dedyu 1980, Lyakhov 1961, Mordukhaĭ-Boltovskoĭ 1960).*
- Obesogammarus obesus *has a wide distribution in Caspian, Azov, Black Seas. Originally low in Danube, now as high as Budapest (middle Danube) (Nesemann et al. 1996).*
- Obesogammarus obesus *was also found in Ukraine, Austria, Germany, Russia.*

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
	7

- Obesogammarus obesus *has disperal rates: 130 km/yr (mean); 424km/yr (max) (Leuven et al. 2009).*
- *In particular, the amphipod* O. obesus *extended its distribution area 500 km upstream in the river during a short period from 1958 to 1972 (Shakhmatova and Antonov 1988).*

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing the establishment and spread of this species)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent the establishment and/or spread of this species	0
Unknown	U
	0

- *There are none; only control meausres to prevent this species introduction.*

Establishment Potential Scorecard				
Points	**Probability for Establishment**	A. Total Points (pre-adjustment)		114
>100	High	**Adjustments**		
		B. Critical species	A*(1- 0%)	114
51-99	Moderate	C. Natural enemy	B*(1-10%)	102.6
		Control measures	C*(1- 0%)	102.6
0-50	Low	**Potential for Establishment**		High
# of questions answered as "unable to determine"	**Confidence Level**			
0-1	High	Total # of questions unknown		1
2-5	Moderate			
6-9	Low	Confidence Level		High
>9	Very low			

Section C: Potential for Impact

IMPACT POTENTIAL RESULTS

Environmental: High

Socio-Economic: Low

Beneficial: Low

***Obesogammarus obesus* has the potential for high environmental impact if introduced to the Great Lakes.**

Obesogammarus obesus is an intermediate host of the tapeworm *Amphilina foliacea* (Dubinina 1974). *Amphilina foliacea* affects Acipenserideae species at 20-93% infection rates and reduces reproductive success (Bauer et al. 2002). Acipenserideae fish get infected this tapeworm when it feeds on amphipods that carry it. *Amphilina foliacea* can potentially pose a hazard to lake sturgeon (*Acipenser fulvescens*), a near-threatened species of concern in the Great Lakes. Another host of *Amphilina foliacea*, *Gammarus fasciatus* currently occurs in the Great Lakes (Kipp 2014). *Amphilina foliacea* has not been reported in the Great Lakes but occurs in western North America (Choudhury and Dick 2001), so the threat of *Amphilina foliacea* due to the introduction of *Obesogammarus obesus* may be novel, but it is likely that its effects would be local. There is evidence that it may outcompete other species; the high density of *Obesogammarus obesus* (3,300 individuals/m^2) in the Danube River in Germany was associated with the displacement of several other amphipod species (Tittizer et al. 2000). By reaching high densities and preying on zoobenthos, *Obesogammarus obesus* has the potential to negatively impact zoobentos populations (Elexová and Némethová 2003). As a prey of non-native round goby (*Neogobius* *melanostomus*), the presence of *Obesogammarus obesus* may result in an increase in population size of these invasive fish (Borza et al. 2009).

There is little or no evidence to support that *Obesogammarus obesus* has the potential for significant socio-economic impact if introduced to the Great Lakes.

It has not been reported that *Obesogammarus obesus* poses a threat to human health or water quality. There is no evidence that this species negatively impacts infrastructure, economic sectors, or the aesthetic appeal of the areas it inhabit. It has the potential to impact recreation by reducing the abundance of lake sturgeon; however, it is unknown if it has significant impacts.

There is little or no evidence to support that *Obesogammarus obesus* has the potential for significant beneficial impacts if introduced to the Great Lakes.

It has not been indicated that *Obesogammarus obesus* can be used for the control of other organisms or improving water quality. There is no evidence to suggest that this species is commercially, recreationally, or medically valuable. It does not have significant positive ecological impacts.

POTENTIAL ENVIRONMENTAL IMPACT

NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6 √
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1
Not significantly	0
Unknown	U

- Obesogammarus obesus *is an intermediate host of the tapeworm Amphilina foliacea, which can infect sturgeon species in Acipenserideae at 20-93% infection rates and can affect reproductive success. The Lake Sturgeon (*Acipenser fulvescens*) in the Great Lakes is a near-threatened species of concern, and any disruption to reproduction could impact this species (Dubinina 1974).*

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1 √
Not significantly	0
Unknown	U

- Obesogammarus obesus *can attain densities of up to 3,300 individuals/m² in the upper reaches of impoundments of the navigable section of the Danube River in German which are characterized by widespread silt deposits (Tittizer et al. 2000). These high abundances of* O. obesus *were associated with a displacement of several other amphipod species (i.e., Dikerogammarus spp.) (Tittizer et al. 2000).*
- *While no studies in the Great Lakes, has been found to be more numerous than many serious invaders like* Dikerogammarus villosus *(Žganec et al. 2009) or with abundances just below species abundant in the Great Lakes (e.g., E. ishnus) (Pockl 1994 pers comm. in Holdich and Pöckl 2007).*
- Obesogammarus obesus *is found to be highly abundant in several areas (40-100%) (Bódis et al. 2012, Elexová and Némethová 2003).*
- Obesogammarus obesus *dominates periphyton in shallow depths (Protasov and Silaeva 2010).*
- Obesogammarus obesus *is more common than* D. villosus *and* P. robustoides *in the damlake (Popescu-Marinescu et al. 2001).*
- Obesogammarus obesus *is the largest size class distribution (>50% of Danube and its main tributaries); dominant in communities (Borza et al. 2009).*

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in the food web)	6
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	1 √
Not significantly	0
Unknown	U

- *With 30% of its diet as a predator, the significant densities of* O. obesus *have potential to have predation effects. This may contribute to displacement of other zoobenthos (Elexová and Némethová 2003).*
- Obesogammarus obesus *is a significant portion of round and bighead goby diet (Borza et al. 2009).*

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0
Unknown	U √

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1
Not significantly	0
Unknown	U √

E6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1
Not significantly	0
Unknown	U √

Environmental Impact Total	**8**
Total Unknowns (U)	**3**

Scoring		
Score	# U	**Impact**
>5	Any	**<u>High</u>**
2-5	Any	Moderate
0	0-1	Low
1	0	
0	≥2	Unknown
1	≥1	

<u>POTENTIAL SOCIO-ECONOMIC IMPACT</u>

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1
Not significantly	0 √
Unknown	U

S2) Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1
Not significantly	0 √
Unknown	U

S3) Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0 √
Unknown	U

S4) Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6
Yes, but negative consequences have been small	1
Not significantly	0

Unknown	U √

- Obesogammarus obesus *could impact recreation through decline of lake sturgeon.*

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

Socio-Economic Impact Total	**0**
Total Unknowns (U)	**1**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**Low**
1	0	
0	≥2	Unknown
1	≥1	

POTENTIAL BENEFICIAL EFFECT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular effect. An "Unknown" response is appropriate if the potential for a particular effect might be inferred but has not been explicitly reported or if there is an unresolved debate about a particular effect.

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1
Not significantly	0 √
Unknown	U

B2) Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?

Yes, it is economically important to at least one of these industries	6
Yes, but its economic contribution is small	1
Not significantly	0 √
Unknown	U

B3) Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local communities and/or tourism	6
It is sometimes employed recreationally, but adds little value to local communities or tourism	1
Not significantly	0 √
Unknown	U

B4) Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR It is potentially important to medicine or research and is currently being or scheduled to be studied	1
Not significantly	0 √
Unknown	U

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1
Not significantly	0 √
Unknown	U

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1
Not significantly	0 √
Unknown	U

Beneficial Effect Total	**0**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**Low**
1	0	
0	≥2	Unknown
1	≥1	

Scientific Name: *Pontogammarus robustoides*
G.O. Sars, 1894

Common Name: Scud

Synonyms:

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: Unlikely

Hitchhiking/fouling: Unlikely

Unauthorized intentional release: Unlikely

Stocking/planting/escape from recreational culture: Unlikely

Escape from commercial culture: Unlikely

Transoceanic shipping: Moderate

***Pontogammarus robustoides* has a moderate probability of introduction to the Great Lakes (Confidence level: High).**

Potential pathway(s) of introduction: Transoceanic Shipping

Pontogammarus robustoides has expanded its range from the Ponto-Caspian basin and is now present in coastal waters of the Baltic Sea, as well as connecting river basins (bij de Vaate et al. 2002). Within the Baltic, this species has dispersed via both by ballast water transport and hull fouling (Arbačiauskas and Gumuliauskaite 2007, Grabowski et al. 2003, Grabowski and Bacela 2005, Jażdżewski et al. 2002, Reinhold and Tittizer 1997, Reinhold and Tittizer 1999). As a high volume of Great Lakes shipping traffic originates from this region, ballast is a likely mechanism of further species spread (Grigorovich et al. 2003).

It has been proposed that based on its natural occurrence in brackish waters, *P. robustoides* may be able survive partial to complete ballast water exchange (Grigorovich et al. 2003). As a result, this species has been assessed by some researchers as having a high Great Lakes invasion risk from both BOB and NOBOB vessels (Grigorovich et al. 2003). However, under current mandatory ballast water regulations (saltwater flushing of at least 30 ppt), the number of individuals entering the Great Lakes is likely to be reduced due to physiological salinity constraints. Nevertheless, Santagata et al. (2008) reported partial survival of *P. robustoides* individuals exposed for 48 hours to full strength seawater (34 PSU).

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100
No, this species does not occur near waters connected to the Great Lakes basin and/or is not mobile or able to be transported by wind or water.	0 √
Unknown	U

- Pontogammarus robustoides *is a Ponto-Caspian species that has invaded much of Europe (bij de Vaate et al. 2002).*

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0 √
Unknown	U

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a) Is this species sold at aquarium/pet/garden stores ("brick & mortar" or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100
No, this species this species is rarely/never sold.	0 √
Unknown	U

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0 √
Unknown	U

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is <u>likely</u> to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces), this activity <u>may</u> occur within 20 km of the basin because of the species' popularity/value.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100
No, this species is not commercially cultured in or transported through the Great Lakes region.	0 √
Unknown	U

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80 √
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40
No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0
Unknown	U

- *Within the Baltic, this species has dispersed via both ballast water transport and hull fouling (Arbačiauskas and Gumuliauskaite 2007, Grabowski et al. 2003, Grabowski and Bacela 2005, Jażdżewski et al. 2002, Reinhold and Tittizer 1997, Reinhold and Tittizer 1999). As a high volume of Great Lakes shipping traffic originates from this region, ballast is a likely mechanism of further species spread (Grigorovich et al. 2003).*
- *It has been proposed that based on its natural occurrence in brackish waters,* P. robustoides *may be able survive partial to complete ballast water exchange (Grigorovich et al. 2003). As a result, this species has been assessed by some researchers as having a high Great Lakes invasion risk from both BOB and NOBOB vessels (Grigorovich et al. 2003).*

- *However, under current mandatory ballast water regulations (saltwater flushing of at least 30 ppt), the number of individuals entering the Great Lakes is likely to be reduced due to physiological salinity constraints. Nevertheless, Santagata et al. (2008) reported partial survival of* P. robustoides *individuals exposed for 48 hours to full strength seawater (34 ppt).*

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5 √
Yes, but this species has neither been observed in ballast/fouling ships entering the Great Lakes nor in ports in direct trade with the Great Lakes.	Score x 0.1
No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0
Unknown	U

- Pontogammarus robustoides *has expanded its range from the Ponto-Caspian basin and is now present in coastal waters of the Baltic Sea, as well as connecting river basins (bij de Vaate et al. 2002).*

Vector Potential Scorecard					
Vector		**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind		**0**	x	**0**	Unlikely
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.		**0**	x	**0**	Unlikely
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)		**0**	x	**0**	Unlikely
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)		**0**	x	**0**	Unlikely
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)		**0**	x	**0**	Unlikely
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling		**80**	x 0.5	**40**	Moderate
Total Unknowns (U)	**0**	**Confidence Level**		High	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

ESTABLISHMENT POTENTIAL RESULTS

Status: **Not established in North America, including the Great Lakes**

***Pontogammarus robustoides* has a high probability of establishment if introduced to the Great Lakes (Confidence level: Moderate).**

Pontogammarus robustoides is a non-specific feeder (bij de Vaate et al. 2002), consuming detritus, sediments, unicellular green algae, and filamentous green algae, as well as oligochaetes and chironomids (Berezina et al. 2005). It has an invasion history of outcompeting a variety of other macroinvertebrate species in Europe, including the North American native amphipod *Gammarus lacustris* (see Impacts). When abundant, *P. robustoides* significantly contributes to the diets of various fish species (Arbačiauskas and Gumuliauskaite 2007, Bubinas 1979), but the extent to which this predation will have an effect on potential populations in the Great Lakes is unknown.

The climatic conditions of the native (Ponto-Caspian) and introduced (Baltic) ranges of *P. robustoides* are very similar to those of the Great Lakes. *Pontogammarus robustoides* overwinters in its native range (Ponto-Caspian) and introduced areas (Baltic Sea and major river basins) (Bacela and Konopacka 2005). This species is able to survive in moderately wide temperature and salinity ranges encompassing conditions occurring in the Great Lakes. Its preferred ionic concentrations may limit the distribution of *P. robustoides* to the four lower Lakes (Michigan, Huron, Erie, Ontario), as spring chloride concentrations in Lake Superior are regularly very low (< 2 mg/L) (USEPA 2012).

Increased salinization is likely to be beneficial to the establishment of *P. robustoides*, as this species occurs naturally in brackish water (Dobrzycka-Krahel and Surowiec 2011, Romanova 1959). This species is likely to benefit from shorter ice cover duration.

Arbačiauskas (2002) hypothesized that oxygen concentration is the principal limiting factor in determining the survival and sustainability of populations of Ponto-Caspian amphipods, but *P. robustoides* has greater tolerance to low oxygen these other amphipod invaders in the Baltic Sea (Dedyu 1980). As oxygen content in higher latitude eutrophic waters that are ice covered for a substantial portion of the year is often reduced (Arbačiauskas 2002 and 2005), *P. robustoides* tends to occur in eutrophic waters only when ice cover is infrequent (Grabowski 2011); ice covered eutrophic waters may kill off established populations (Arbačiauskas and Gumuliauskaite 2007). Anoxic conditions, as present in the central basin of Lake Erie (USEPA 2012), may prevent *P. robustoides* from establishing in some regions of the Great Lakes.

Disturbance factors such as eutrophication, macroalgal blooms, and oxygen deficiency may facilitate the success of this species when introduced to a new environment, as competition for resources with established species becomes reduced (Berezina 2007).This species prefers to inhabit lenthic as opposed to lotic environments due to its inability to disperse against flow (Bacela and Konopacka 2005, Berezina and Panov 2003, Grabowski and Grudule et al. 2007, Jażdżewski et al. 2002, Zettler 2002), making the majority of the Great Lakes basin suitable habitat for establishment with respect to water movement. A high diversity of available habitats in a colonized area may facilitate survival and establishment of populations of *P. robustoides* by reducing niche overlap between various size classes (Czarnecka et al. 2010).

Pontogammarus robustoides is a highly fecund species among Ponto-Caspian invaders in Europe and one of Poland's most fecund amphipods, producing more eggs than other species of similar size, (Bacela and Konopacka 2005, bij de Vaate et al. 2002). This species undergoes rapid maturity, producing three generations per year with short (4-5 week) generation times (Bacela and Konopacka 2005). The autumn generation typically overwinters, but in thermally polluted waters (e.g., hydroelectric cooling water discharge), this species may reproduce year round (Kiticyna 1980); therefore, warming waters as a result of climate change could be beneficial to its invasion success.

The invasion pattern of *P. robustoides* across Europe was very similar in magnitude and rate to another European mass invader, *Dikerogammarus villosus*, both of which have spread across the entire European continent in roughly 50 years (bij de Vaate et al. 2002). The spread of *P. robustoides* follows "jump" dispersal patterns, suggesting the involvement of anthropogenic factors in its expansion (Arbačiauskas and Gumuliauskaite 2007). Once introduced, it has quickly become established throughout many major European water bodies, reaching densities of up to 2700 individuals/m^2 in some locations (Arbačiauskas and Gumuliauskaite 2007, Berezina et al. 2005).

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
	8

- Pontogammarus robustoides *is able to survive in a relatively wide range of temperature (able to coexist with other invasive European amphipods tolerating water temperatures of ~5-30°C), and salinity, occurring naturally in salinities of 13 PSU (Romanova 1959) and showing partial survival (~50%) when exposed to 34 PSU for 48 hours (Santagata et al. 2008).*

- *It is able to survive at oxygen concentrations as low as 0.209 mg/L, the lowest reported for any of the invasive European amphipods (Dedyu 1980).*
- *Viable populations are able to exist with sodium concentrations as low as 3.4 mg/L (Arbačiauskas and Gumuliauskaite 2007) and to reproduce at potassium concentrations as low as 10-15 mg/L (Berezina and Panov 2003). Disturbance factors such as eutrophication, macroalgal blooms and oxygen deficiency may facilitate the success of this species when introduced to a new environment, as competition for resources with established species becomes reduced (Berezina 2007).*

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9
Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
	8

- Pontogammarus robustoides *overwinters in its native range (Ponto-Caspian) and introduced areas (Baltic Sea and major river basins), undergoing a breeding peak in early October to produce individuals that will survive to breed early the following April (Bacela and Konopacka 2005).This species is able to survive at oxygen concentrations as low as 0.209 mg/L (Dedyu 1980). When water temperatures drop below 5°C, this species migrates to deeper waters habitats (Berezina et al. 2005)*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
	9

- *This species shows a non-specific food preference (bij de Vaate et al. 2002) and diet flexibility, able to feed on detritus, sediments, unicellular green algae, and filamentous green algae, as well as oligochaetes and chironomids (Berezina et al. 2005).*

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9
Somewhat likely (This species is known to have superior competitive abilities, but there	6

are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	0
Unknown	U
	8

- *This species has a history of outcompeting a variety of other macroinvertebrate species throughout its invaded European territory, including the North American native amphipod* Gammarus lacustris *(see Impact section).*

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
	9

- *Bij de Vaate et al. (2002) classify* P. robustoides *as a species with high fecundity among the successful Ponto-Caspian invaders across Europe.*
- *Bacela and Konopacka (2005) have observed this species to be one of Poland's most fecund amphipods, with females laying more eggs than individuals of other species with similar body size.*

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
	7

- *This species undergoes rapid maturity, producing three generations per year with short (4-5 week) generation times (Bacela and Konopacka 2005).*

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- *This species is a Ponto-Caspian native, a region where climatic conditions are very similar to those of the Great Lakes.*
- *The Great Lakes and Ponto-Caspian region are "climatically compatible," which is one of the attributing factors to the success of Ponto-Caspian species in the Great Lakes (Reid and Orlova 2002).*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- *The water temperature (~6-30°C) and salinity range (0-13 ppt) tolerated by* P. robustoides *within its native range are well within the ranges occurring in the Great Lakes.*
- *This species prefers to inhabit lentic as opposed to lotic environments due to its inability to disperse against flow (Bacela and Konopacka 2005, Berezina and Panov 2003, Grabowski and Grudule et al. 2007, Jażdżewski et al. 2002, Zettler 2002), making the majority of the Great Lakes basin suitable habitat for establishment with respect to water movement.*
- *Abiotic factors and climatic conditions in the Ponto-Caspian region are quite similar to the Great Lakes, making the region compatible (Grigorovich et al. 2003, Reid and Orlova 2002).*
- *Great Lakes underwent similar anthropogenic eutrophication as the Ponto-Caspian region (Reid and Orlova 2002). Surface water temperature is similar between the Great Lakes and Ponto-Caspian seas (Grigorovich et al. 2003, Reid and Orlova 2002, USEPA 2008).*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0
Unknown	U
	8

- *A high diversity of habitats available in a colonized area may facilitate survival and establishment of populations of* P. robustoides *by reducing niche overlap between various size classes (Czarnecka et al. 2010).*
- Pontogammarus robustoides *is known to exist in waters with ionic concentrations as low at 185 mg/L total, with 3.4 mg Na^+/L and therefore ~5.0 mg Cl^-/L (Arbačiauskas and Gumuliauskaite 2007). Such preferred ionic concentrations may limit this species distribution to the four lower Lakes (Michigan, Huron, Erie, Ontario), as spring chloride concentrations in Lake Superior are regularly below 2 mg/L (USEPA 2012).*
- *It is hypothesized that O_2 concentrations are the principal limiting factor in determining the survival and sustainability of populations of Ponto-Caspian amphipods (Arbačiauskas 2002). Anoxic conditions present in the central basin of Lake Erie (USEPA 2012) may prevent* P. robustoides *from establishing there, as eutrophic conditions under ice cover may destroy an established populations (Arbačiauskas and Gumuliauskaite 2007).*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0
Unknown	U
	9

- *This species is likely to benefit from shorter ice cover duration, as oxygen content in higher latitude eutrophic waters that are ice covered for a substantial portion of the year is often reduced (Arbačiauskas 2002, Arbačiauskas 2005). Therefore, this species tends to occur only in eutrophic waters where ice cover is infrequent (Grabowski 2011).*
- *Increased salinization (Rahel and Olden 2008) is also likely to be beneficial to the establishment of* P. robustoides *in the Great Lakes, as this species occurs naturally in salinities up to 13 ppt (Romanova 1959) and is able to survive in waters with much higher salinity (Dobrzycka-Krahel and Surowiec 2011).*

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9

Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
	9

- *This species displays a non-specific food preference (bij de Vaate et al. 2002) and a flexible diet, able to feed on detritus, sediments, unicellular green algae, and filamentous green algae, as well as oligochaetes and chironomids (Berezina et al. 2005). None of these food sources are limiting in the Great Lakes.*

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Great Lakes and is not likely to be introduced	-80% total points (at end)
Unknown	U
	9

- *There is no critical species required by* P. robustoides.

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the	6

development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes)	
Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0
Unknown	U
	0

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0
Unknown	U
	U

- *When abundant,* P. robustoides *significantly contributes to the diets of various fish species (Arbačiauskas and Gumuliauskaite 2007, Bubinas 1979), though the extent to which this predation will have an effect on potential populations in the Great Lakes is unknown.*

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9
Frequent, moderate inocula	6
Frequent, small inocula OR infrequent, large inocula	3
Infrequent, small or moderate inocula	0
Unknown	U
	U

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
	9

- *The invasion pattern of this species across Europe was very similar in magnitude and rate to another European mass invader,* Dikerogammarus villosus, *both of which have spread across the entire European continent in roughly 50 years (bij de Vaate et al. 2002).*
- *It has quickly become established throughout many major European water bodies, reaching densities of 2700 individuals/m^2 in some locations (Arbačiauskas and Gumuliauskaite 2007, Berezina et al. 2005).*

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
	8

- *Within the Baltic, this species is known to have dispersed via both ballast water transport and hull fouling (Arbačiauskas and Gumuliauskaite 2007, Grabowski et al. 2003, Grabowski and Bacela 2005, Jażdżewski et al. 2002, Reinhold and Tittizer 1997, Reinhold and Tittizer 1999).*
- *Hull fouling is likely the most important dispersal mechanism over short distances by slow moving vessels (Arbačiauskas and Gumuliauskaite 2007). The spread of* P. robustoides *follows jump dispersal patterns, suggesting the involvement of anthropogenic factors in its expansion (Arbačiauskas and Gumuliauskaite 2007).*

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are	-90% total points (at

highly effective in preventing the establishment and spread of this species)	end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent the establishment and/or spread of this species	0
Unknown	U
	0

Establishment Potential Scorecard				
Points	**Probability for Establishment**	A. Total Points (pre-adjustment)		117
>100	High	**Adjustments**		
		B. Critical species	A*(1- 0%)	117
51-99	Moderate	C. Natural enemy	B*(1- 0%)	117
		Control measures	C*(1- 0%)	117
0-50	Low	**Potential for Establishment**		High
# of questions answered as "unable to determine"	**Confidence Level**			
0-1	High	Total # of questions unknown		2
2-5	Moderate			
6-9	Low	Confidence Level		Moderate
>9	Very low			

Section C: Potential for Impact

IMPACT POTENTIAL RESULTS

Environmental: Moderate

Socio-Economic: Low

Beneficial: Moderate

***Pontogammarus robustoides* has the potential for moderate environmental impact if introduced to the Great Lakes.**

In habitats across Europe where *P. robustoides* is well established and numerous, significant declines in species richness and diversity, as well as reductions in body length of other macroinvertebrates, have been observed (Arbačiauskas and Gumuliauskaite 2007). In Lithuanian water bodies with abundant populations of *P. robustoides*, competitive exclusion of the native amphipod *Gammarus lacustris* has been observed (Arbačiauskas 2002, Arbačiauskas 2005). Additionally, asymmetrical intraguild predation may be primarily responsible for the displacement of other Baltic Sea gammarid species (Arbačiauskas and Gumuliauskaite 2007), including a smaller invasive amphipod, *Gmelinoides fasciatus* in some habitats in the eastern Gulf of Finland (Berezina and Panov 2003), and indigenous *Gammarus duebeni* and *Gammarus zaddachi* in the Vistula Lagoon (Jażdżewski et al. 2004). Large numbers of *P. robustoides* have reduced the densities of benthic detritivores in the stony littoral zone of Neva Bay in the Gulf of Finland (Berezina and Panov 2003). When abundant, this species may also negatively affect populations of the freshwater isopod *Asellus aquaticus* as a result of direct predation (Arbačiauskas 2005). However, in moderate abundances, the negative impacts exerted by *P. robustoides* on species diversity are less severe (Arbačiauskas and Gumuliauskaite 2007).

Pontogammarus robustoides may be a vector of non-native fish parasites (e.g., Trematoda, Acanthocephala) (Sulgostowska and Vojtkova 1992). Additionally, *P. robustoides* may affect the composition and abundance of littoral macrophytes through heavy grazing pressure, as seen with the Great Lakes nuisance algae *Cladophora* in the eastern Gulf of Finland (Berezina et al. 2005). Populations in this study were able to consume 4-5 g (dry weight) *Cladophora* per day.

There is little or no evidence to support that *Pontogammarus robustoides* has the potential for significant socio-economic impacts if introduced to the Great Lakes.

The reductions in size and diversity of macroinvertebrate communities associated with the introduction of *P. robustoides* (Arbačiauskas and Gumuliauskaite 2007) may diminish food availability for native fish species; however, these specific effects have not yet been documented. Additionally, this species is not known to be a vector of any human pathogens (Grabowski 2011).

***Pontogammarus robustoides* has the potential for moderate beneficial effects if introduced to the Great Lakes.**

The initial and subsequent intentional introductions of this species into the Baltic Sea were intended to improve fishery production (Arbačiauskas and Gumuliauskaite 2007); when abundant, *P. robustoides* makes significant contributions to fish diet (Bubinas 1979). However, its contribution to the diet of fish species has never been precisely quantified, except for an unconfirmed 20% increase in fishery production in a few reports (Arbačiauskas and Gumuliauskaite 2007). Further, this species is considered an important factor in macroalgal bloom control through food web interactions. When populations are dense, *P. robustoides* can have a dramatic grazing impact on *Cladophora* (a widespread nuisance macroalgae in the Great Lakes) biomass in the littoral zone (Berezina et al. 2005).

POTENTIAL ENVIRONMENTAL IMPACT

NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1 √
Not significantly	0
Unknown	U

- Pontogammarus robustoides *may be a vector of non-native fish parasites (e.g., Trematoda, Acanthocephala) (Sulgostowska and Vojtkova 1992).*

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1 √
Not significantly	0
Unknown	U

- Pontogammarus robustoides *has a history of outcompeting other macroinvertebrate species throughout its invaded range in Europe. In habitats where* P. robustoides *is well established and numerous, significant declines in species richness and diversity, as well as reductions in body length of other macroinvertebrates, have been observed (Arbačiauskas and Gumuliauskaite 2007).*
- *In Lithuanian water bodies with abundant populations* of P. robustoides*, competitive exclusion of the native amphipod* Gammarus lacustris *has been observed (Arbačiauskas 2002, Arbačiauskas 2005).*
- *In the brackish Vistula Lagoon, a decline of indigenous* Gammarus duebeni *and* Gammarus zaddachi *was reported parallel to the appearance of* P. robustoides *as a result of intraguild predation (Jażdżewski et al. 2004).*
- *Large numbers of* P. robustoides *have reduced the densities of benthic detritivores in the stony littoral zone of Neva Bay in the Gulf of Finland (Berezina and Panov 2003).*
- *In moderate abundances, the negative impacts exerted by* P. robustoides *on species diversity are less severe (Arbačiauskas and Gumuliauskaite 2007).*

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in the food web)	6
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	1 √

Not significantly	0
Unknown	U

- *Additionally, asymmetrical intraguild predation may be primarily responsible for the displacement of other Baltic Sea gammarid species when* P. robustoides *is introduced (Arbačiauskas and Gumuliauskaite 2007), including a smaller invasive amphipod,* Gmelinoides fasciatus *in some habitats in the eastern Gulf of Finland (Berezina and Panov 2003).*
- *When abundant, this species may negatively affect populations of the freshwater isopod* Asellus aquaticus *as a result of direct predation (Arbačiauskas 2005).*

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0 √
Unknown	U

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1
Not significantly	0 √
Unknown	U

E6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1 √
Not significantly	0
Unknown	U

- Pontogammarus robustoides *may affect the composition and abundance of littoral macrophytes through heavy grazing pressure, as seen with Great Lakes nuisance algae* Cladophora *in the eastern Gulf of Finland. Populations in this study were able to consume 4-5 g (dry weight)* Cladophora *per day (Berezina et al. 2005).*

Environmental Impact Total	**4**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	**Moderate**
0	0-1	Low
1	0	
0	≥2	Unknown
1	≥1	

POTENTIAL SOCIO-ECONOMIC IMPACT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1
Not significantly	0 √
Unknown	U

- *This species is not known to be a vector of any human pathogens (Grabowski 2011).*

S2) Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1
Not significantly	0 √
Unknown	U

S3) Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6

Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0 √
Unknown	U

S4) Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0
Unknown	U √

- *The reductions in size and diversity of macroinvertebrate communities associated with the introduction of* P. robustoides *(Arbačiauskas and Gumuliauskaite 2007) may diminish food availability for native fish species; however, these specific effects have not yet been documented.*

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

Socio-Economic Impact Total	**0**
Total Unknowns (U)	**1**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate

0	0-1	**Low**
1	0	
0	≥2	Unknown
1	≥1	

POTENTIAL BENEFICIAL EFFECT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular effect. An "Unknown" response is appropriate if the potential for a particular effect might be inferred but has not been explicitly reported or if there is an unresolved debate about a particular effect.

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1 √
Not significantly	0
Unknown	U

- *This species is considered an important factor in macroalgal bloom control through food web interactions (Berezina et al. 2005).*
- *When populations are dense,* P. robustoides *can have a dramatic grazing impact on Cladophora biomass (a nuisance macroalgae present in the Great Lakes) in the littoral zone (Berezina et al. 2005).*

B2) Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?

Yes, it is economically important to at least one of these industries	6
Yes, but its economic contribution is small	1 √
Not significantly	0
Unknown	U

- *The initial and subsequent intentional introductions of this species into the Baltic Sea were intended to improve fishery production (Arbačiauskas and Gumuliauskaite 2007); when abundant,* P. robustoides = *makes significant contributions to fish diet (Bubinas 1979). However, its contribution to the diet of fish species has never been precisely quantified, except for an unconfirmed 20% increase in fishery production in a few reports (Arbačiauskas and Gumuliauskaite 2007).*

B3) Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local communities and/or tourism	6
It is sometimes employed recreationally, but adds little value to local communities or tourism	1
Not significantly	0 √

Unknown	U

B4) Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR It is potentially important to medicine or research and is currently being or scheduled to be studied	1
Not significantly	0 √
Unknown	U

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1
Not significantly	0 √
Unknown	U

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1
Not significantly	0 √
Unknown	U

Beneficial Effect Total	**2**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	**<u>Moderate</u>**
0	0-1	Low
1	0	

0	≥2	Unknown
1	≥1	

A.5 Crustaceans - Cladocerans

Scientific Name: *Cornigerius maeoticus maeoticus*
Pengo, 1879

Common Name: Waterflea

Synonyms:

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: Unlikely

Hitchhiking/fouling: Unlikely

Unauthorized intentional release: Unlikely

Stocking/planting/escape from recreational culture: Unlikely

Escape from commercial culture: Unlikely

Transoceanic shipping: Moderate

Cornigerius maeoticus maeoticus **has a moderate probability of introduction to the Great Lakes (Confidence level: High).**

Potential pathway(s) of introduction: Transoceanic Shipping

Cornigerius maeoticus maeoticus is not known to hitchhike or foul, and is not stocked or commercially cultured in the Great Lakes basin. It does not currently occur near waters connected to the Great Lakes basin and has yet to be observed in the ballast water of ships entering the Great Lakes.

Cornigerius maeoticus maeoticus is present in the Baltic Sea, which has trade connections to the Great Lakes (Krylov et al. 1999, Panov et al. 2007, Rodionova 2005, Sopanen 2008); thus *Cornigerius maeoticus maeoticus* may be transported to the Great Lakes via shipping. This species produces resting eggs that may survive transport in ballast water (Sopanen 2008). *Cornigerius maeoticus maeoticus* can tolerate temperatures ranging from 11 to 23°C and salinities up to 24% (Aladin 1995, Panov et al. 2007). *Cornigerius maeoticus maeoticus* may be introduced to the Great Lakes via ships declaring "No Ballast on Board" (NOBOB) that are exempt from ballast water exchanage. A study showed that the majority of ships entering the Great Lakes are NOBOB vessels and 43% of these ships contain residual water with less than 10‰ salinity (Johengen et al. 2005). In that study, the temperature of the residual water from the vessels sampled ranged from -0.7 to 23.9°C; thus *Cornigerius maeoticus maeoticus* is likely to survive the salinity and temperature of the NOBOB ballast water.

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100
No, this species does not occur near waters connected to the Great Lakes basin and/or is not mobile or able to be transported by wind or water.	0 √
Unknown	U

- Cornigerius maeoticus maeoticus *occurs naturally in the Ponto-Caspian basin. Its native and invaded range includes the Black Sea, the Sea of Azov, and the freshwater rivers of the basin (Mordukhaĭ-Boltovskoĭ and Rivier 1971, Panov et al. 2007).*

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0 √
Unknown	U

- Cornigerius maeoticus maeoticus *is most likely to be introduced to the Great Lakes basin through ballast water. There is no indication in the literature of biofouling or hitchhiking (Panov et al. 2007, USEPA 2008).*
- Cornigerius maeoticus maeoticus *produces resting eggs that could possibly foul ships, but it is unlikely (Panov et al. 2007, Sopanen 2008).*

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a) Is this species sold at aquarium/pet/garden stores ("brick & mortar" or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100
No, this species this species is rarely/never sold.	0 √
Unknown	U

- *The only commercial use for* C. maeoticus maeoticus *would be through scientific supply companies. A thorough search of companies (Fisher Scientific, Carolina Biological Supply, and various companies found through Google searches) concluded with no evidence of this species being used by scientific supply companies.*

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0 √
Unknown	U

- *There is no indication in the literature that* C. maeoticus maeoticus *occurs naturally in North America or that there would be any interest stocking (Mordukhaĭ-Boltovskoĭ and Rivier 1971, Panov et al. 2007).*

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is <u>likely</u> to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5

This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces), this activity may occur within 20 km of the basin because of the species' popularity/value.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100
No, this species is not commercially cultured in or transported through the Great Lakes region.	0 √
Unknown	U

- *There is no record either in the literature or online of* C. maeoticus maeoticus *being commercially cultured or transported.*

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80 √
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40
No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current	0

ballast water regulations.	
Unknown	U

- Cornigerius maeoticus maeoticus *has been shown to survive in a range of temperature from 11 to 23˚C, and can tolerate both fresh and brackish water, up to 13‰ (Panov et al. 2007).*
- Cornigerius maeoticus maeoticus *also produces resting eggs which could aid in its invasion (Sopanen 2008).*
- *Multiple papers have stated that ballast water is a likely vector for transport of* C. maeoticus maeoticus *(Krylov et al. 1999, Rodionova 2005).*

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5 √
Yes, but this species has neither been observed in ballast/fouling ships entering the Great Lakes nor in ports in direct trade with the Great Lakes.	Score x 0.1
No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0
Unknown	U

- Cornigerius maeoticus maeoticus *is native to the Black, Azov, and Caspian seas and the lower reaches of the lower reaches of Danube, Dnieper, and Bug rivers (Panov et al. 2007).*
- *It has spread throughout the Ponto-Caspian region into areas where shipping is prevalent (e.g., Volga, Don, and Dnieper reservoirs), as well as into the eastern Baltic Sea; this shipping traffic provides an invasion corridor from the eastern Baltic Sea to the Great Lakes (Krylov et al. 1999, Panov et al. 2007, Rodionova 2005, Sopanen 2008).*

Vector Potential Scorecard					
Vector		**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind		**0**	x	**0**	Unlikely
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.		**0**	x	**0**	Unlikely
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)		**0**	x	**0**	Unlikely
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)		**0**	x	**0**	Unlikely
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)		**0**	x	**0**	Unlikely
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling		**80**	x 0.5	**40**	Moderate
Total Unknowns (U)	**0**	**Confidence Level**		High	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

ESTABLISHMENT POTENTIAL RESULTS

Status: **Not established in North America, including the Great Lakes**

***Cornigerius maeoticus maeoticus* has a moderate probability of establishment if introduced to the Great Lakes (Confidence level: High).**

Cornigerius maeoticus maeoticus is native to the Ponto-Caspian basin, occurring in the Black Sea, the Sea of Azov, and the freshwater rivers of the basin (Mordukhaĭ-Boltovskoĭ and Rivier 1971, Panov et al. 2007). Where it has been already introduced, it is inoculated in small quantities and infrequently (Rodionova 2005). Historically, it has been established locally outside its native range and its spread was facilitated by human activities (Panov et al. 2007, Rodionova 2005). The native and introduced ranges of *Cornigerius maeoticus maeoticus* have similar climate and abiotic conditions to that of the Great Lakes (USEPA 2008, Reid and Orlova 2002, Grigorovich et al. 2003). This species prefers inhabiting the metalimnion in large lakes; thus it is likely to find a suitable habitat in the Great Lakes. It is unlikely that the adult forms of this species are capable of overwintering in the Great Lakes due to its temperature range of 11-23°C (Panov et al. 2007). *Cornigerius maeoticus maeoticus* produces resting stages that are likely to survive winters in the Great Lakes. *Cornigerius maeoticus maeoticus* may adapt well to climate change in the Great Lakes; increase in salinization and temperature may render the Great Lakes more suitable for this species (Mordukhaĭ-Boltovskoĭ and Rivier 1971, Panov et al. 2007, Reid and Orlova 2002).

Cornigerius maeoticus maeoticus feeds on smaller planktonic organisms such as microcrustaceans that are abundant in the Great Lakes. This species will likely find a suitable food source if introduced to the Great Lakes (Panov et al. 2007). *Cornigerius maeoticus maeoticus* is preyed on by planktivorous fish and larger predatory zooplankton. If this species is introduced to the Great Lakes, its establishment may be limited by predation.

Several studies predict that *Cornigerius maeoticus maeoticus* will establish in the Great Lakes due to its ability to produce resting eggs (Panov et al. 2007, Rodionova 2005, Sopanen 2008). It is capable of parthenogenesis (Mordukhaĭ-Boltovskoĭ 1967). This species has a higher fecundity that other similar species in the Baltic Sea (Panov et al. 2007); however, its fecundity may be more moderate in waters of lower salinity (Aladin 1995, Mordukhaĭ-Boltovskoĭ and Rivier 1971).

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
	5

- Cornigerius maeoticus maeoticus *has been recorded to survive from 11 to 23˚C, a salinity range from freshwater to 1.7 ppt, and in a variety of nutrient levels (Panov et al. 2007).*

- *A study of salinity tolerance by Aladin (1995) found that under laboratory conditions* C. maeoticus maeoticus *showed upper limits of 20 and 24 g L^{-1} in Caspian and Aral Sea water respectively. Aladin (1995) also found individuals within the Caspian Sea in the range of 6.0 g L^{-1} to 12.5 g L^{-1}.*
- *Mordukhaĭ-Boltovskoĭ and Rivier (1971) noted that* C. maeoticus maeoticus *preferred 3-8% salinity levels in the north Caspian Sea, also tolerating fresh waters.*

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9
Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
	8

- Cornigerius maeoticus maeoticus *could not survive these conditions during most life stages. However, it produces resting "winter" eggs that would survive the conditions specified (Panov et al. 2007).*
- *Due to the climatic similarities between the Great Lakes and Ponto-Caspian regions (Reid and Orlova 2002) this species most likely endures similar overwintering conditions in its native range.*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
	4

- *Research on the particular diet of* C. maeoticus maeoticus *and its relatives is limited. However, it is known to prey upon small planktonic organisms, such as other microcrustaceans (Mordukhaĭ-Boltovskoĭ and Rivier 1971, Panov et al. 2007).*

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	6

Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	0
Unknown	U
	4

- *Research on the competitive ability of* C. maeoticus maeoticus *is limited; however, some closely related species that have successfully invaded the Great Lakes have been studied more thoroughly.* Cercopagis pengoi *has been shown to be controlled effectively by larger local planktivorous fish populations, but in some cases it has outcompeted the smaller planktivorous fishes (Panov et al. 2007).*
- Cercopagis pengoi *comes from the same order and section (Onychopoda) as* C. maeoticus maeoticus *but from a different family (Cristescu and Hebert 2005).* Cercopagis pengoi *has similar physiological tolerances and feeding behaviors, although it is more motile (Panov et al. 2007). In papers discussing the invasion history of cladocerans in the Ponto-Caspian region,* C. maeoticus maeoticus *and* C. pengoi *are cited as the most probable or most recent to invade, along with* Evadne anonyx *(Panov et al. 2007, Rodionova 2005, Sopanen 2008).*

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
	6

- *Panov et al. 2007 found that* C. maeoticus maeoticus *had higher fecundity than other similar species in the Baltic Sea, including* C. pengoi *that has successfully invaded the Great Lakes. Other papers have found the fecundity rates of* C. maeoticus maeoticus *to be more moderate in less saline regions (Aladin 1995, Mordukhaĭ-Boltovskoĭ and Rivier 1971).*

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid	0

establishment in new environments)	
Unknown	U
	9

- *Multiple papers have predicted that* C. maeoticus maeoticus *will successfully invade the Great Lakes due to its ability to produce resting eggs (Panov et al. 2007, Rodionova 2005, Sopanen 2008).*
- Cercopagis pengoi *has similar physiological tolerances and reproductive strategies as* C. maeoticus maeoticus *and it invaded the Great Lakes 15 years ago (Panov et al. 2007).*

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- *The Great Lakes and Ponto-Caspian region are climatically compatible, which is one of the attributing factors to the success of Ponto-Caspian species in the Great Lakes (Reid and Orlova 2002).*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- *Abiotic factors and climatic conditions of the native and introduced ranges of* C. maeoticus maeoticus *are quite similar to the Great Lakes, making the region compatible (Grigorovich et al. 2003, Reid and Orlova 2002).*
- *Great Lakes underwent similar anthropogenic eutrophication as the Ponto-Caspian region (Reid and Orlova 2002). Surface water temperature is similar between the Great Lakes and Ponto-Caspian seas (Grigorovich et al. 2003, Reid and Orlova 2002, USEPA 2008).*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0
Unknown	U
	6

- *Like most related species,* C. maeoticus maeoticus *prefers the metalimnion (middle water layer) in larger lakes, at around 10-20 m deep, during the peak season (Mordukhaĭ-Boltovskoĭ and Rivier 1971). This habitat is readily available in the Great Lakes, although it may already be in high demand.*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0
Unknown	U
	9

- Cornigerius maeoticus maeoticus *would benefit from an increase in salinity and slightly warmer water temperatures in the Great Lakes (Mordukhaĭ-Boltovskoĭ and Rivier 1971, Panov et al. 2007, Reid and Orlova 2002).*

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0

Unknown	U
	9

- Cornigerius maeoticus maeoticus *preys upon smaller planktonic organisms such as microcrustaceans (Panov et al. 2007). These plankton are extremely plentiful in the Great Lakes basin. An already established invasive predator,* C. pengoi, *demonstrates that similar predators will have an appropriate food source readily available (Bushnoe et al. 2003, Panov et al. 2007).*

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Great Lakes and is not likely to be introduced	-80% total points (at end)
Unknown	U
	9

- *There is no indication in any literature that* C. maeoticus maeoticus *requires another species for a critical life stage. There is definitely room for more research to be done concerning the basic biology and ecology of the species, but of the research that has been done, there is no mention (Aladin 1995, Mordukhaĭ-Boltovskoĭ and Rivier 1971, Panov et al. 2007)*

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes)	6
Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established	3

in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0
Unknown	U
	0

- Cornigerius maeoticus maeoticus *could possibly benefit from nonindigenous plankton being established as an extra food source (Aladin 1995, Mordukhaĭ-Boltovskoĭ and Rivier 1971, Panov et al. 2007). Although this is a possibility, there is no recorded example of this happening, and there is already an established food source available.*

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0
Unknown	U
	-30%

- Cornigerius maeoticus maeoticus, *as well as its relatives, are naturally predated upon by planktivorous fish and other predatory zooplankton. While there is no record of* C. maeoticus maeoticus *being specifically controlled by any particular predator, this has sometimes been the case for its relative* C. pengoi*, a well established invasive species in the Great Lakes (Panov et al. 2007). Local indigenous and nonindigenous species have been shown to have varying levels of control on* C. pengoi *in its native and introduced ranges.*
- *A Lake Ontario study found that* C. pengoi *is effectively consumed by Alewife,* Alosa pseudoharengus*, and Rainbow Smelt,* Osmerus mordax. *This study also found that even in areas with strong fish predation,* C. pengoi *still could reach high abundances (Bushnoe et al. 2003, Panov et al. 2007).*
- *Various studies looking at the relationship between* Bythotrephes longimanus *and* C. pengoi *have been conducted (Panov et al. 2007).* Bythotrephes longimanus *is a larger onychopod that also preys upon smaller plankton in both native and introduced ranges. Panov et al. (2007) note that* B. longimanus *seems to be the most effective predator of* C. pengoi.

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9
Frequent, moderate inocula	6
Frequent, small inocula OR infrequent, large inocula	3
Infrequent, small or moderate inocula	0
Unknown	U
	1

- *In the cases where* C. maeoticus maeoticus *was introduced by transoceanic shipping, it was an infrequent inoculum that was very small (e.g., a few individuals) (Rodionova 2005).*

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
	7

- Cornigerius maeoticus maeoticus *has spread throughout the Ponto-Caspian region. This is greatly aided by human activity along one specific invasion corridor. There are multiple papers documenting the annual spread of this species and its relatives (Panov et al. 2007, Rodionova 2005).*

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
	7

- *Over the past 40 years,* C. maeoticus maeoticus *has spread throughout the Ponto-Caspian region. This spread was greatly accelerated by human activities (Panov et al. 2007, Rodionova 2005).*

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing the establishment and spread of this species)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent the establishment and/or spread of this species	0
Unknown	U
	0

- *The major control measure in the Great Lakes would be ballast water management options such as ballast water exchange. While this could be an effective measure, relatives of* C. maeoticus maeoticus *have successfully invaded the Great Lakes after the implantation of these measures (Panov et al. 2007, Rodionova 2005). This however relates to the introduction of a species, not establishment.*

Establishment Potential Scorecard				
Points	**Probability for Establishment**	A. Total Points (pre-adjustment)		100
>100	High	**Adjustments**		
		B. Critical species	A*(1- 0%)	100
51-99	Moderate	C. Natural enemy	B*(1- 30%)	70
		Control measures	C*(1- 0%)	70
0-50	Low	**Potential for Establishment**		Moderate
# of questions answered as "unable to determine"	**Confidence Level**			
0-1	High	Total # of questions unknown		0
2-5	Moderate			
6-9	Low	Confidence Level		High
>9	Very low			

Section C: Potential for Impact

IMPACT POTENTIAL RESULTS

Environmental: Unknown

Socio-Economic: Low

Beneficial: Low

Current research on the potential for environmental impacts to result from *Cornigerius maeoticus maeoticus* if introduced to the Great Lakes is inadequate to support proper assessment.

There is insufficient information available to determine if *Cornigerius maeoticus maeoticus* poses a threat to other species or water quality. There are no reports on how it affects or interacts with other species. It is unknown whether this species alters the physical components of the ecosystem.

There is little or no evidence to support that *Cornigerius maeoticus maeoticus* has the potential for significant socio-economic impact if introduced to the Great Lakes.

It has not been reported that *Cornigerius maeoticus maeoticus* poses a threat to human health or water quality. There is no evidence that this species negatively impacts infrastructure, economic sectors, recreational activities and associated tourism, or the aesthetic appeal of the areas it inhabits.

There is little or no evidence to support that *Cornigerius maeoticus maeoticus* has the potential for significant beneficial impacts if introduced to the Great Lakes.

It has not been indicated that *Cornigerius maeoticus maeoticus* can be used for the control of other organisms or improving water quality. There is no evidence to suggest that this species is commercially, recreationally, or medically valuable. It does not have significant positive ecological impacts.

POTENTIAL ENVIRONMENTAL IMPACT

NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1
Not significantly	0 √
Unknown	U

- *There is little literature describing the biology of this species in particular. Some papers compare* Cornigerius maeoticus maeoticus *to its relatives, which do not pose any particular threat or hazard to native species (Mordukhaĭ-Boltovskoĭ and Rivier 1971, Panov et al. 2007).*

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1
Not significantly	0
Unknown	U √

- Cornigerius maeoticus maeoticus *is a predatory cladoceran that generally feeds on smaller planktonic crustaceans. There is no direct evidence that* C. maeoticus maeoticus *would out-compete native species for food sources, however closely related species such as* Cercopagis pengoi *have been shown to do so once introduced in the Great Lakes (Panov et al. 2007, Rodionova 2005).*

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in the food web)	6
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	1
Not significantly	0 √
Unknown	U

- *There is no direct evidence of* C. maeoticus maeoticus *altering predator prey relationships.*

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0
Unknown	U √

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected water quality to some extent, but the alterations and resulting adverse	1

effects have been limited or inconsistent (as compared with above statement)	
Not significantly	0 √
Unknown	U

- *There has been some work done on the basic biology and ecology of this species but in general it is lacking. There is however no indication that* C. maeoticus maeoticus *would have any effect on water quality (Mordukhaĭ-Boltovskoĭ and Rivier 1971, Panov et al. 2007).*

E6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1
Not significantly	0 √
Unknown	U

- *There has been some work done on the basic biology and ecology of this species but in general it is lacking. There is however no indication that* C. maeoticus maeoticus *would have any effect on the physical components of the ecosystem (Mordukhaĭ-Boltovskoĭ and Rivier 1971, Panov et al. 2007).*

Environmental Impact Total	**0**
Total Unknowns (U)	**2**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	Low
1	0	
0	≥2	**Unknown**
1	≥1	

POTENTIAL SOCIO-ECONOMIC IMPACT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1
Not significantly	0 √
Unknown	U

- *There is no indication in the literature that* C. maeoticus maeoticus *would have any adverse effects on human health. It is not a known carrier of any disease or pathogen and there is no record suggesting it would magnify toxin levels (Mordukhaĭ-Boltovskoĭ and Rivier 1971, Panov et al. 2007).*

S2) Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1
Not significantly	0 √
Unknown	U

- *There is no indication in the literature that* C. maeoticus maeoticus *would cause damage to any infrastructure. It is a planktonic crustacean that does not possess any means to damage infrastructure (Mordukhaĭ-Boltovskoĭ and Rivier 1971, Panov et al. 2007).*

S3) Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0 √
Unknown	U

- *There is no indication in the literature that* C. maeoticus maeoticus *would negatively affect water quality. It does prey upon other planktonic crustaceans that could possibly prey upon algae, but there is no record of a significant effect resulting from this predation (Mordukhaĭ-Boltovskoĭ and Rivier 1971, Panov et al. 2007).*

S4) Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

- *There is no indication in the literature that* C. maeoticus maeoticus *would negatively affect any markets or economic sectors. It could pose competition for smaller planktivorous fish, but there has been no explicit record of this occurring (Mordukhaĭ-Boltovskoĭ and Rivier 1971, Panov et al. 2007)*
- *A closely related species,* C. pengoi*, which has invaded the Great Lakes has demonstrated competition with smaller planktivorous fish (Panov et al. 2007).*

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

- *There is no indication in the literature that* C. maeoticus maeoticus *would inhibit any recreational activities. It could pose competition for smaller planktivorous fish, but there has been no explicit record of this occurring (Mordukhaĭ-Boltovskoĭ and Rivier 1971, Panov et al. 2007)*
- *A closely related species,* C. pengoi*, has been shown to be competitive with smaller planktivorous fish and to foul fishing lines (Panov et al. 2007).*

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

- *There is no indication in the literature that* C. maeoticus maeoticus *would diminish any aesthetic or natural value (Mordukhaĭ-Boltovskoĭ and Rivier 1971, Panov et al. 2007).*

Socio-Economic Impact Total	**0**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**Low**
1	0	
0	≥2	Unknown
1	≥1	

POTENTIAL BENEFICIAL EFFECT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular effect. An "Unknown" response is appropriate if the potential for a particular effect might be inferred but has not been explicitly reported or if there is an unresolved debate about a particular effect.

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1
Not significantly	0 √
Unknown	U

- *There is no indication in the literature that* C. maeoticus maeoticus *would act as a biological control for any nonindigenous organisms (Mordukhaĭ-Boltovskoĭ and Rivier 1971, Panov et al. 2007).*
- *However, a closely related species,* C. pengoi*, has been shown to control and be controlled by other nonindigenous species in its native and introduced habitats (Panov et al. 2007).*

B2) Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?

Yes, it is economically important to at least one of these industries	6
Yes, but its economic contribution is small	1
Not significantly	0 √
Unknown	U

- *There is no indication in the literature that* C. maeoticus maeoticus *would be commercially valuable.*

B3) Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local communities and/or tourism	6
It is sometimes employed recreationally, but adds little value to local communities or tourism	1
Not significantly	0 √
Unknown	U

- *There is no indication in the literature that* C. maeoticus maeoticus *would be recreationally valuable.*

B4) Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR It is potentially important to medicine or research and is currently being or scheduled to be studied	1
Not significantly	0 √

Unknown	U

- *There is no indication in the literature that* C. maeoticus maeoticus *would be valuable for research. The only research that has been done on it has been related to its invasion and distribution (Mordukhaĭ-Boltovskoĭ and Rivier 1971, Panov et al. 2007, Rodionova 2005).*

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1
Not significantly	0 √
Unknown	U

- *There is no indication in the literature that* C. maeoticus maeoticus *would remove toxins or pollutants or otherwise improve water quality. It is a predatory cladoceran that feeds upon smaller cladocerans and plankton that would not have any effect on water quality (Mordukhaĭ-Boltovskoĭ and Rivier 1971, Panov et al. 2007).*

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1
Not significantly	0 √
Unknown	U

- *There is no indication in the literature that* C. maeoticus maeoticus *would have a positive ecological impact.*

Beneficial Effect Total	**0**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**<u>Low</u>**
1	0	
0	≥2	Unknown
1	≥1	

Scientific Name: *Daphnia cristata*
G.O. Sars, 1862

Common Name: Waterflea

Synonyms:

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: Unlikely

Hitchhiking/fouling: Unlikely

Unauthorized intentional release: Unlikely

Stocking/planting/escape from recreational culture: Unlikely

Escape from commercial culture: Unlikely

Transoceanic shipping: High

***Daphnia cristata* has a high probability of introduction to the Great Lakes (Confidence level: High).**

Potential pathway(s) of introduction: Transoceanic Shipping

Daphnia cristata is predicted to have potential for introduction to the Great Lakes via ballasts of vessels as well as ships that declare "No Ballast on Board" (Grigorovich et al. 2003). In general, this species does not tolerate a wide range of adverse conditions, but it has been found in residual water from a ship that entered the Great Lakes basin (Duggan et al. 2005, Wonham et al. 2005). In addition, this species is capable of producing ephippia eggs that are resistant to harsh conditions (Benzie 2005). It has been reported that *Daphnia cristata* has a high risk of introduction to the Great Lakes (Grigorovich et al. 2003). *Daphnia cristata* does not currently occur near waters connected to the Great Lakes basin.

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100
No, this species does not occur near waters connected to the Great Lakes basin and/or is not mobile or able to be transported by wind or water.	0 √
Unknown	U

- Daphnia cristata *is widely distributed in temperate regions in Europe and Asia but not recorded from North America (Benzie 2005).*

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0 √
Unknown	U

- *The only recorded vector that could transport this species to the Great Lakes basin is within ballast water (Duggan et al. 2005).*

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a) Is this species sold at aquarium/pet/garden stores ("brick & mortar" or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100
No, this species this species is rarely/never sold.	0 √
Unknown	U

- *The only commercial use for* Daphnia cristata *would be through scientific supply companies. A thorough search of companies (Fisher Scientific, Carolina Biological Supply, and various companies found through Google searches) concluded with no evidence of this species being used by scientific supply companies.*

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0 √
Unknown	U

- *Daphnia cristata* is widely distributed in temperate regions in Europe and Asia but not recorded from North America (Benzie 2005).

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is likely to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces), this activity may occur within 20 km of the basin because of the species' popularity/value.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100
No, this species is not commercially cultured in or transported through the Great Lakes region.	0 √
Unknown	U

- *The only commercial use for* Daphnia cristata *would be through scientific supply companies. A thorough search of companies (Fisher Scientific, Carolina Biological Supply, and various companies found through Google searches) concluded with no evidence of this species being used by scientific supply companies.*

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80 √
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40
No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0
Unknown	U

- Daphnia cristata *does not generally tolerate a wide range of adverse conditions, but a study has shown individuals surviving in ballast water transported to the Great Lakes basin (Duggan et al. 2005, Wonham et al. 2005).*
- *Ships declaring NOBOB have been shown to harbor water habitable to* Daphnia cristata *(Johengen et al. 2005).*

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1 √
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5
Yes, but this species has neither been observed in ballast/fouling ships entering the Great	Score x 0.1

Lakes nor in ports in direct trade with the Great Lakes.	
No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0
Unknown	U

- Daphnia cristata *does not generally tolerate a wide range of adverse conditions, but a study has shown individuals surviving in ballast water transported to the Great Lakes basin (Duggan et al. 2005, Wonham et al. 2005).*
- Daphnia cristata *is widely distributed in temperate regions in Europe and Asia (Benzie 2005).*

Vector Potential Scorecard					
Vector		**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind		**0**	x	**0**	Unlikely
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.		**0**	x	**0**	Unlikely
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)		**0**	x	**0**	Unlikely
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)		**0**	x	**0**	Unlikely
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)		**0**	x	**0**	Unlikely
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling		**80**	x 1	**80**	High
Total Unknowns (U)	**0**	**Confidence Level**		High	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

<u>ESTABLISHMENT POTENTIAL RESULTS</u>

Status: **Not established in North America, including the Great Lakes**

***Daphnia cristata* has a moderate probability of establishment if introduced to the Great Lakes (Confidence level: High).**

Daphnia cristata is widely distributed in temperate regions in Europe and Asia (Benzie 2005). The native range of this species, the Ponto-Caspian basin, has a similar climate to the Great Lakes (USEPA 2008). The Great Lakes exhibit seasonality and similar stratification as its native range. *Daphnia cristata* may be capable of overwintering in the Great Lakes basin; it naturally occurs in waters that are 0-3°C and can tolerate waters with low oxygen levels (Rivier 2005). This species has the potential to tolerate pollution in the Great Lakes; in Finland, this species is present in eutrophic lakes (Horppila et al. 2000). It has been suggested that *Daphnia cristata* is released from ships that enter the Great Lakes in low number and frequency, so its potential for establishment may be somewhat limited (Duggan et al. 2005, Johengen et al. 2005).

Daphnia cristata is likely to find a food source in the Great Lakes. It feeds on phytoplankton (Benzie 2005). *Daphnia cristata* may be resistant to predation by fish and benefits from high predation pressure (Hessen et al. 1995). It can avoid predation by planktivorous fish by avoiding predators in space and changing its morphology in times of high predation pressure (Pijanowska 1992). This species benefits from the presence of planktivorous fish that eat other cladocerans (Amundsen et al. 2009, Nyberg 1998). *Daphnia cristata* is among the most abundant cladoceran in Lake Hiidenvesi, Finland, making up 38-88% of the cladoceran biomass (Alajärvi and Horppila 2004, Tallberg et al. 1999). Evidence suggests that a predatory cladoceran *Leptodora kindti* feeds on *Daphnia cristata* and regulates their population in Lake Hiidenvesi (Uusitalo et al. 2003). *Leptodora kindti* is also found in the Laurentian Great lakes (Barbiero et al. 2001); thus, *Leptodora kindti* may limit the establishment of *Daphnia cristata* in the Great Lakes, if introduced.

The ability of *Daphnia cristata* for parthogenesis may facilitate its establishment, especially if only females get introduced to the Great Lakes (Petrusek et al. 2005). It reproduces sexually in harsh conditions, producing ephippia that are highly resistant (Benzie 2005). This species is able to expand its distribution by migrating from lakes to connected reservoirs (Mordukhaĭ- Boltovskoĭ 1979).

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
	5

- Daphnia cristata *tolerates an overall moderate to low range of conditions. It has been shown to occur in pH levels greater than 5, low calcium levels, moderate (2.5-8 mg/L) dissolved oxygen levels, temperatures at 0-3˚C, and has been shown to be positively correlated with chlorophyll* a *levels but no reported ranges (Cairns and Yan 2009, Rivier 2005, Wærvågen et al. 2002).*
- Daphnia cristata *can tolerate lake temperatures in southern Norway average 13-14°C during summer (Hobaek et al. 2012, Holtan 1973).*

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9
Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
	8

- Daphnia cristata *has been shown to occur naturally in waters that are 0-3˚C. It has been shown to survive in low oxygen levels (0.1 mg/L) but has been recorded in higher abundance in 2.5-8 mg/L (Rivier 2005).*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
	3

- Daphnia cristata*, as any other* Daphnia*, feeds on particles in the water column. They can survive off of various types of plankton and bacteria but not for long. For continued survival they need a diet of phytoplankton that is particular to their filtering capacity (Benzie 2005).*

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	0
Unknown	U
	5

- Daphnia cristata *is not a strong competitor for resources but can withstand predation pressure better than other cladocerans. Whenever large predation pressure is present,* D. cristata *is the dominant or one of the dominant cladocerans. When this pressure is removed, larger species of cladocerans prevail (Amundsen et al. 2009, Nyberg 1998).*

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
	2

- Daphnia cristata *has been shown to have similar fecundity to a closely related species,* Daphnia longispina *(Rivier 2005).* D. longispina *may have 3 eggs per clutch, which is small compared to larger* Daphnia *species such as* D. magna *(up to 100 eggs per clutch) (Ebert 2005).*

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	9

Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
	6

- Daphnia cristata *is known to produce ephippia that are highly resistant and could aid in establishment and has been known to survive in ballast water. However, literature has only predicted the invasion of the Great Lakes but not the establishment (Grigorovich et al. 2003, Wonham et al. 2005).*

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- Daphnia cristata *occurs mostly in sub arctic regions in Europe and Asia; lakes here experience seasonality and develop similar stratification (Benzie 2005, Rivier 2005, Russia 2013)*
- *The Great Lakes and Ponto-Caspian region are climatically compatible, which is one of the attributing factors to the success of Ponto-Caspian species in the Great Lakes (Reid and Orlova 2002).*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- Daphnia cristata *occurs mostly in sub arctic regions in Europe and Asia (Benzie 2005). Water conditions such as dissolved oxygen, and temperature can be somewhat similar but not exactly the same (Horppila 1997, Johengen et al. 2000, Rivier 2005). This species has been shown to occur in lakes with a specific calcium threshold which the Great Lakes can meet (Beeton et al. 1965).*
- *Abiotic factors and climatic conditions in the Ponto-Caspian region are quite similar to the Great Lakes, making the region compatible (Grigorovich et al. 2003, Reid and Orlova 2002).*
- *Great Lakes underwent similar anthropogenic eutrophication as the Ponto-Caspian region (Reid and Orlova 2002). Surface water temperature is similar between the Great Lakes and Ponto-Caspian seas (Grigorovich et al. 2003, Reid and Orlova 2002, USEPA 2008).*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0
Unknown	U
	7

- Daphnia cristata *occurs naturally in systems that have similar habitats to the Great Lakes, specifically Lake Huron (Johengen et al. 2000, NINA 2007).*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0
Unknown	U
	0

- Daphnia cristata *naturally occurs in waters that are similar to the larger Great Lakes but are generally colder and experience ice cover. If the Great Lakes were to increase in water temperature or lose ice cover, they would become unsuitable for* D. cristata *(Rivier 2005).*

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
	8

- Daphnia cristata*, as with any other daphnid species, feeds on algae and phytoplankton (Benzie 2005). The amount of algae and phytoplankton in a lake can be indicated by the levels of chlorophyll in the lake. Many of the Great Lakes still contain relatively high levels of algae, for instance, Saginaw Bay (Johengen et al. 2000).*

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Great Lakes and is not likely to be introduced	-80% total points (at end)
Unknown	U
	9

- Daphnia *spp. do not require another species for any critical stages in their life cycles. They reproduce largely by cyclic parthenogenesis and will only switch to sexual reproduction in response to environmental cues (Benzie 2005).*

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of	9

this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes)	6
Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0
Unknown	U
	1

- *Various species of algae and phytoplankton have successfully established in the Great Lakes basin (USGS 2012). These species could be potential food sources for* Daphnia cristata *but would not facilitate its establishment anymore than naturally occurring algae and phytoplankton.*

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0
Unknown	U
	-10%

- Daphnia cristata *is preyed upon by planktivorous fish which are prevalent in the Great Lakes basin. However being one of the smallest* Daphnia *species, it is known to be resistant to predation pressure and often becomes the dominant cladoceran species with high predation levels (NINA 2007, Nyberg 1998, Tallberg et al. 1999).*

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9

Frequent, moderate inocula	6
Frequent, small inocula OR infrequent, large inocula	3
Infrequent, small or moderate inocula	0
Unknown	U
	1

- *The possible vector for introduction of* Daphnia cristata *is through ballast water. However a study done on ballast water entering the Great Lakes only showed single individuals surviving (Johengen et al. 2005).*

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
	2

- *There is little record of invasion as a possible result of human activities of* Daphnia cristata*. There is a detailed account of* D. cristata *immigrating downstream into the Volgograd reservoir as a result of more reservoirs being constructed (Mordukhaĭ-Boltovskoĭ 1979). These reservoirs are connected directly to lakes where* D. cristata *occurs naturally.*

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
	6

- *In the instance of* D. cristata *spreading into the Volgograd reservoir it spread quickly to other reservoirs (Mordukhaĭ-Boltovskoĭ 1979). This is attributed to a very high rate of introduction (simply flowing downstream), which would be a combination of human activities (creating the reservoir) and natural means.*

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing the establishment and spread of this species)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent the establishment and/or spread of this species	0
Unknown	U
	0

- *There are no existing control measure that could prevent the establishment of* Daphnia cristata *once introduced.*

Establishment Potential Scorecard				
Points	**Probability for Establishment**	A. Total Points (pre-adjustment)		79
>100	High	**Adjustments**		
		B. Critical species	A*(1- 0%)	79
51-99	Moderate	C. Natural enemy	B*(1- 10%)	71.1
		Control measures	C*(1- 0%)	71.1
0-50	Low	**Potential for Establishment**		Moderate
# of questions answered as "unable to determine"	**Confidence Level**			
0-1	High	Total # of questions unknown		0
2-5	Moderate			
6-9	Low	Confidence Level		High
>9	Very low			

Section C: Potential for Impact

<u>IMPACT POTENTIAL RESULTS</u>

Environmental: Unknown

Socio-Economic: Low

Beneficial: Moderate

Current research on the potential for environmental impacts to result from *Daphnia cristata* if introduced to the Great Lakes is inadequate to support proper assessment.

Daphnia cristata does not pose a threat to other species or water quality. It does not out-compete native species for available resources. It is not a strong competitor, but becomes abundant by escaping predation in the presence of planktivorous fish, which consume other zooplankton species (Amundsen et al. 2009, Nyberg 1998).

There is little or no evidence to support that *Daphnia cristata* has the potential for significant socio-economic impact if introduced to the Great Lakes.

It has not been reported that *Daphnia cristata* poses a threat to human health or water quality. There is no evidence that this species negatively impacts infrastructure, economic sectors, recreational activities and associated tourism, or the aesthetic appeal of the areas it inhabits.

***Daphnia cristata* has the potential for moderate beneficial effects if introduced to the Great Lakes.**

Its diet may include toxic algae (Benzie 2005). It may be able to remove a negligible amount of toxic algae. When predation pressure from planktivorous fish is high, the abundance of *Daphnia cristata* increases (Amundsen et al. 2009, Nyberg 1998). If fish predation removes a large portion of phytoplankton consumers from the water body, it may result in an increase in chlorophyll concentration and an algal bloom (Andersson et al. 1978). The increase in abundance of *Daphnia cristata* during times of high predation pressure may replace the loss of phytoplankton consumers and suppress an algal bloom to some extent.

POTENTIAL ENVIRONMENTAL IMPACT

NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1
Not significantly	0 √
Unknown	U

- Daphnia cristata *poses no natural hazard to other species.*

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1
Not significantly	0 √
Unknown	U

- Daphnia cristata *is not a strong competitor. It generally loses out in competition and is recorded in higher abundances only in the presence of planktivorous fish (Amundsen et al. 2009, Nyberg 1998).*

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in the food web)	6
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	1
Not significantly	0 √
Unknown	U

- Daphnia cristata *has been shown to occupy available niches when present (Wærvågen et al. 2002). It is generally is recorded only in the presence of planktivorous fish (Amundsen et al. 2009, Nyberg 1998, Wærvågen et al. 2002).*

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0
Unknown	U √

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected water quality to some extent, but the alterations and resulting adverse	1

effects have been limited or inconsistent (as compared with above statement)	
Not significantly	0 √
Unknown	U

- *There have been no reports of any environmental effects from this organism.* Daphnia cristata *is a very small organism and generally fills a specialized niche (Amundsen et al. 2009, NINA 2007). Its effect on water quality would be negligible.*

E6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1
Not significantly	0
Unknown	U √

- *There have been no reports of any environmental effects from this organism.*

Environmental Impact Total	**0**
Total Unknowns (U)	**2**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	Low
1	0	
0	≥2	**Unknown**
1	≥1	

POTENTIAL SOCIO-ECONOMIC IMPACT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might *be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.*

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1
Not significantly	0 √
Unknown	U

- *There has been no evidence of* Daphnia cristata *posing any threat to human health.*

S2) Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1
Not significantly	0 √
Unknown	U

- *There has been no evidence of* Daphnia cristata *damaging infrastructure.*

S3) Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0 √
Unknown	U

- *There has been no evidence of* Daphnia cristata *affecting water quality.*

S4) Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

- *There has been no evidence of* Daphnia cristata *affecting markets or economic sectors*.

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6

Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

- *There has been no evidence of* Daphnia cristata *inhibiting recreational activities or tourism*.

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

- *There has been no evidence of* Daphnia cristata *diminishing the aesthetic or natural value of the lakes it inhabits.*

Socio-Economic Impact Total	**0**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**Low**
1	0	
0	≥2	Unknown
1	≥1	

POTENTIAL BENEFICIAL EFFECT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular effect. An "Unknown" response is appropriate if the potential for a particular effect might be inferred but has not been explicitly reported or if there is an unresolved debate about a particular effect.

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1

Not significantly	0 √
Unknown	U

- Daphnia cristata *as a filter feeder could possibly be used to control algae species although there have been no reports of it successfully doing so.*

B2) Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?

Yes, it is economically important to at least one of these industries	6
Yes, but its economic contribution is small	1
Not significantly	0 √
Unknown	U

- *There is no evidence of* Daphnia cristata *having any sort of commercial value*.

B3) Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local communities and/or tourism	6
It is sometimes employed recreationally, but adds little value to local communities or tourism	1
Not significantly	0 √
Unknown	U

- *There is no evidence of* Daphnia cristata *having any sort of recreational value*.

B4) Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR It is potentially important to medicine or research and is currently being or scheduled to be studied	1
Not significantly	0 √
Unknown	U

- *There is no evidence of* Daphnia cristata *having significant medicinal or research value. It has been recorded in various natural observations and studies but not in any significant way.*

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1 √
Not significantly	0
Unknown	U

- Daphnia cristata *is a filter feeder and part of its diet could include toxic algae but this effect would be negligible compared to larger filter feeders (Benzie 2005).*

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1 √
Not significantly	0
Unknown	U

- Daphnia cristata *could possibly fill in a gap in natural food webs. It has been known to occur when fish predation pressure is very high (Amundsen et al. 2009, Nyberg 1998).*

Beneficial Effect Total	**2**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	**Moderate**
0	0-1	Low
1	0	
0	≥2	Unknown
1	≥1	

Scientific Name: *Podonevadne trigona ovum*
Zernov, 1901

Common Name: Waterflea

Synonyms:

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: Unlikely

Hitchhiking/fouling: Unlikely

Unauthorized intentional release: Unlikely

Stocking/planting/escape from recreational culture: Unlikely

Escape from commercial culture: Unlikely

Transoceanic shipping: Low

***Podonevadne trigona ovum* has a low probability of introduction to the Great Lakes (Confidence level: high).**

Potential pathway(s) of introduction: Transoceanic Shipping

Podonevadne trigona ovum has not been reported in or near the Great Lakes basin. This species has limited mobility (Zinevici et al. 2011). The eggs of *Podonevadne trigona ovum* may be transported by birds, but it is unlikely that it would be carried overseas. The resting egg stage of this species is hardy and may be able to survive ballast tank environments for long periods of time; however, it may be flushed out during ballast exchange.

It has the potential to be introduced to the Great Lakes if the distribution of *Podonevadne trigona ovum* spreads to the eastern Baltic, and survives transport via an existing invasion corridor between the eastern Baltic and the Great Lakes (Grigorovich et al. 2003, Panov et al. 1999). This species has already been observed outside its native range in the Danube-Black Sea canal, the reservoirs and lagoons of the Bug, Dneipr, Dniestr, Don, and Volga rivers (Zinevici et al. 2011), and Kahovka (Rivier 1998).

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100
No, this species does not occur near waters connected to the Great Lakes basin and/or is	0 √

not mobile or able to be transported by wind or water.	
Unknown	U

- Podonevadne trigona ovum *has not been reported in or near the Great Lakes basin. A characteristic of the* Podonevadne *genus is limited mobility (Zinevici et al. 2011).*

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0 √
Unknown	U

- *While* Podonevadne trigona ovum *eggs may be able to be transported by birds (Zinevici et al. 2011), it is unlikely that the carrier would be capable of transoceanic travel*.

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a) Is this species sold at aquarium/pet/garden stores ("brick & mortar" or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100

No, this species this species is rarely/never sold.	0 √
Unknown	U

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0 √
Unknown	U

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is likely to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces), this activity may occur within 20 km of the basin because of the species' popularity/value.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100
No, this species is not commercially cultured in or transported through the Great Lakes region.	0 √

Unknown	U

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80 √
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40
No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0
Unknown	U

- Podonevadne trigona ovum *has a resting egg stage of its life history that is hardy. However, the species has extremely limited mobility and may be flushed out during ballast exchange*.

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5
Yes, but this species has neither been observed in ballast/fouling ships entering the Great Lakes nor in ports in direct trade with the Great Lakes.	Score x 0.1 √
No, this species does not occur in waters from which shipping traffic to the Great Lakes	Score x 0

originates.	
Unknown	U

- *Zinevici et al. (2011) observed* Podonevadne trigona ovum *in nearly the entire basin of the Danube-Black Sea canal.* Podonevadne trigona ovum *spread rapidly over 20 years from being an occasional species in 1985 to being a persistent species by 2005—64 km in 87 months or less (Zinevici et al. 2011).*
- Podonevadne trigona ovum *has also been recorded in the Black and Caspian seas (Cristescu 2003), as well as the waters of Romania and the reservoirs and lagoons of the Bug, Dnieper, Dniester, Don, and Volga rivers (Zinevici et al. 2011).*

Vector Potential Scorecard				
Vector	**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind	**0**	x	**0**	Unlikely
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.	**0**	x	**0**	Unlikely
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)	**0**	x	**0**	Unlikely
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)	**0**	x	**0**	Unlikely
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)	**0**	x	**0**	Unlikely
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling	**80**	x 0.1	**8**	Low
Total Unknowns (U)	**0**	**Confidence Level**	High	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High
1-2	Moderate

3-5	Low
>5	Very low

Section B: Potential for Establishment

ESTABLISHMENT POTENTIAL RESULTS

Status: **Not established in North America, including the Great Lakes**

***Podonevadne trigona ovum* has a moderate probability of establishment if introduced to the Great Lakes (Confidence level: Moderate).**

The climate of the Great Lakes is similar to the Ponto Caspian basin (USEPA 2008). Its life cycle aligns with the seasons (Zinevici et al. 2011). The resting egg stage that occurs over the winter is hardy and may be able to survive the harsh winters of the Great Lakes basin, but this has not been specifically tested. It reproduces rapidly and has a short generation time. If introduced to the Great Lakes, this species may establish a population via asexual reproduction; in the Danube-Black Sea Canal, the population of *Podonevadne trigona ovum* was formed primarily by parthenogenetic females, a common method of reproduction in favorable environmental conditions. It is likely to find a food source in the Great Lakes because it feeds on ciliates, rotifers, nauplii, small cladocerans, and nanoplanktonic algae (Egloff et al. 1996, Zinevici et al. 2011**).** If established, it may be preyed on by macroinvertebrates and small fish, but may not impact establishment significantly. It has been reported to occur in the Aral Sea as a nonnative species twice (Aladin 1995) and has extended its range to include the Danube-Black Sea canal (Zinevici 2011). It has spread rapidly through all parts of the Danube-Black Sea canal ecosystem in 20 years. It has been reported as a species of concern in Finnish waters (Pienimäki and Leppäkoski 2004).

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
	6

- Podonevadne trigona ovum *has an upper salinity tolerance of 22 g l^{-1} (Aladin and Potts 1995). Tolerance appears to depend on the concentration of chloride, rather than total salinity. Cladocerans in general cannot tolerate anoxic conditions (Havel et al. 2009).*

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9
Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
	8

- Podonevadne trigona ovum *has a resting egg stage that occurs during the winter months that may be capable of surviving harsh winters typical of the Great Lakes region. However, the limits of the resting egg stage have not been tested.*
- *Due to the climatic similarities between the Great Lakes and Ponto-Caspian regions (Reid and Orlova 2002) this species most likely endures similar overwintering conditions in its native range.*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
	8

- Podonevadne trigona ovum *feed mainly on ciliates, rotifers, nauplii, small cladocerans and, in addition, nanoplanktonic algae (Egloff et al. 1996).*

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	0

Unknown	U
	6

- *In the 2011 article, Zinevici et al. described an environment in which* Podonevadne trigona ovum *was the strongest positioned predacious zooplankton in the community found in the Danube canal. This suggests that* Podonevadne trigona ovum *is a strong competitor at certain times of the year.*

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
	U

- *The methods of reproduction are known for* Podonevadne trigona ovum*, but fecundity has not been documented and/or compared to other species in its taxonomic class.*

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
	6

- Podonevadne trigona ovum *population in Danube-Black Sea was formed exclusively by parthenogenetic females, which is a common situation for cladocerans living in permanent aquatic ecosystems characterized by favorable environmental conditions (Zinevici et al. 2011).*

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- *The Great Lakes and Ponto-Caspian region are climatically compatible, which is one of the attributing factors to the success of Ponto-Caspian species in the Great Lakes (Reid and Orlova 2002).*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- *Abiotic factors and climatic conditions in the Ponto-Caspian region are quite similar to the Great Lakes, making the region compatible (Grigorovich et al. 2003, Reid and Orlova 2002).*
- *Great Lakes underwent similar anthropogenic eutrophication as the Ponto-Caspian region (Reid and Orlova 2002). Surface water temperature is similar between the Great Lakes and Ponto-Caspian seas (Grigorovich et al. 2003, Reid and Orlova 2002, USEPA 2008).*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0
Unknown	U
	8

- Podonevadne trigona ovum *is found in Danube-Black Sea canal , prefers very low to no water flow velocity; also, found in heterogeneous environment, submerged and emergent macrophytes in Zinevici et al. (2011), with no specific habitat requirements.*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0
Unknown	U
	9

- Podonevadne trigona ovum *has a high salinity tolerance (Aladin and Potts 1995), and is known to exist in an environment somewhat warmer than the Great Lakes currently are.* Podonevadne trigona ovum *has limited to no mobility, making it susceptible to streamflow patterns.*

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
	8

- *It is likely that* Podonevadne trigona ovum *feed mainly on ciliates, rotifers, nauplii, small cladocerans and, in addition, nanoplanktonic algae (Egloff et al. 1996).*

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being assessed; OR,	9

No, there is no critical species required by the species being assessed	
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Great Lakes and is not likely to be introduced	-80% total points (at end)
Unknown	U
	9

- Podonevadne trigona ovum *has not been observed to require a critical species in order advance to the next stage of the life cycle*.

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes)	6
Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0
Unknown	U
	0

- *The relationships between* Podonevadne trigona ovum *and other species are not documented, but it appears that this species is self-sufficient.* Podonevadne trigona ovum*'s prey may be the only possibility of aid.*

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	-80% total points (at end)

Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0
Unknown	U
	-10%

- *Some predation by macroinvertebrates and small fish, but not enough to impact establishment significantly.*

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9
Frequent, moderate inocula	6
Frequent, small inocula OR infrequent, large inocula	3
Infrequent, small or moderate inocula	0
Unknown	U
	U

- *Ballast exchange may remove most of the viable adults and resting eggs.*

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
	6

- Podonevadne trigona ovum *has been reported to be invasive to the Aral Sea twice (Aladin and Potts 1995), as well as expanding its range in the Danube-Black Sea Canal (Zinevici et al. 2011).* Podonevadne trigona ovum *has also been reported in the Aral Sea, and is a species of concern for Finnish waters (Pienimäki and Leppäkoski 2004).*

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
	8

- Podonevadne trigona ovum *has a life cycle that aligns with the seasons, allowing it to have a short life history and quick reproduction. It has spread through all parts of the Danube-Black Sea Canal ecosystem in 20 years (Zinevici et al. 2011).*

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing the establishment and spread of this species)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent the establishment and/or spread of this species	0
Unknown	U
	0

Establishment Potential Scorecard				
Points	**Probability for Establishment**	A. Total Points (pre-adjustment)		98
>100	High	**Adjustments**		
		B. Critical species	A*(1- 0%)	98
51-99	Moderate	C. Natural enemy	B*(1- 10%)	88.2
		Control measures	C*(1- 0%)	88.2
0-50	Low	**Potential for Establishment**		Moderate
# of questions answered as “unable to determine”	**Confidence Level**			
0-1	High	Total # of questions unknown		2
2-5	Moderate			
6-9	Low	Confidence Level		Moderate
>9	Very low			

Section C: Potential for Impact

IMPACT POTENTIAL RESULTS

Environmental: Moderate

Socio-Economic: Low

Beneficial: Low

***Podonevadne trigona ovum* has the potential for moderate environmental impact if introduced to the Great Lakes.**

This species established in the Danube-Black Sea canal, subsequently outcompeted indigenous species, and was one of the few dominant species in the zooplankton structure (Zinevici et al. 2011). Its presence there has significantly altered the zooplantonic food web. It is not yet known whether this species affects the health or genetics of native populations, impacts water quality, or alters the physical components of the ecosystem.

There is little or no evidence to support that *Podonevadne trigona ovum* has the potential for significant socio-economic impacts if introduced to the Great Lakes.

It has not been reported that *Podonevadne trigona ovum* poses hazards to human health, damages infrastructure, negatively effects water quality, adversely impacts economic sectors, inhibits recreational activities or associated tourism, or diminishes the perceived aesthetic or natural value of the areas it inhabits in a significant manner.

There is little or no evidence to support that *Podonevadne trigona ovum* has the potential for significant beneficial impacts if introduced to the Great Lakes.

There have not been studies that show that *Podonevadne trigona ovum* can act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms. This species is a predatory zooplankton, but is not selective in its feeding behavior, so it is unlikely that it can significantly control populations of other nonindigenous zooplankton. *Podonevadne trigona ovum* does not have significant commercial, recreational, or medical value.

POTENTIAL ENVIRONMENTAL IMPACT

NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1
Not significantly	0
Unknown	U √

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1 √
Not significantly	0
Unknown	U

- *Zinevici et al. (2011) observed* Podonevadne trigona ovum *outcompete the indigenous species in the Danube-Black Sea canal.*

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in the food web)	6
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1 √

AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	
Not significantly	0
Unknown	U

- *Zinevici et al. (2011) indicated that the presence of* P. t. ovum *significantly altered the zooplantonic food web of the environment into which it had invaded, and has also become the dominant predator.*

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0
Unknown	U √

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1
Not significantly	0
Unknown	U √

E6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1
Not significantly	0
Unknown	U √

Environmental Impact Total	**2**
Total Unknowns (U)	**4**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	**Moderate**
0	0-1	Low
1	0	
0	≥2	Unknown
1	≥1	

POTENTIAL SOCIO-ECONOMIC IMPACT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1
Not significantly	0 √
Unknown	U

S2) Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1
Not significantly	0 √
Unknown	U

S3) Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0 √
Unknown	U

S4) Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

Socio-Economic Impact Total	**0**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**<u>Low</u>**
1	0	
0	≥2	Unknown
1	≥1	

POTENTIAL BENEFICIAL EFFECT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular effect. An "Unknown" response is appropriate if the potential for a particular effect might be inferred but has not been explicitly reported or if there is an unresolved debate about a particular effect.

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1
Not significantly	0 √
Unknown	U

- *As a predatory zooplankton,* Podonevadne trigona ovum *may be capable of controlling populations of nonindigenous zooplankton. However,* Podonevadne trigona ovum*'s prey is not well studied.*

B2) Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?

Yes, it is economically important to at least one of these industries	6
Yes, but its economic contribution is small	1
Not significantly	0 √
Unknown	U

B3) Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local communities and/or tourism	6
It is sometimes employed recreationally, but adds little value to local communities or tourism	1
Not significantly	0 √
Unknown	U

B4) Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR It is potentially important to medicine or research and is currently being or scheduled to be studied	1
Not significantly	0 √
Unknown	U

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1
Not significantly	0 √
Unknown	U

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1
Not significantly	0 √
Unknown	U

Beneficial Effect Total	**0**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**<u>Low</u>**
1	0	
0	≥2	Unknown
1	≥1	

A.6 Crustaceans - Copepods

Scientific Name: *Calanipeda aquaedulcis*
Kritchagin 1873

Common Name: Calanoid Copepod

Synonyms:

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: Unlikely

Hitchhiking/fouling: Unlikely

Unauthorized intentional release: Unlikely

Stocking/planting/escape from recreational culture: Unlikely

Escape from commercial culture: Unlikely

Transoceanic shipping: Moderate

***Calanipeda aquaedulcis* has a moderate probability of introduction to the Great Lakes (Confidence Level: High)**

Potential Pathway(s): Transoceanic Shipping (ballast water)

Calanipeda aquaedulcis has not been reported to occur in North or South America (Svetlichny et al. 2012b). There is no evidence that suggests that *Calanipeda aquaedulcis* is currently stocked, cultured, or sold commercially in the Great Lakes region. This species is not known to attach to recreational gear and is not being transported through the Great Lakes region. The potential risk for invasion originates from the established populations in the Baltic Sea basin, which is an area that has direct trade connections with the Great Lakes (NBIC 2009).

There is a possibility for *Calanipeda aquaedulcis* to be introduced to the Great Lakes if it survives overseas transport originating in the Baltic Sea. It produces resting eggs that may be resistant to salinity increases during ballast exchange, but may be flushed in the process (Frisch et al. 2006, Svetlichny et al. 2012b, Wonham et al. 2005). The adult forms are osmo-conformers that can tolerate a wide range of salinity and may survive ballast water exchange as well (Svetlichny et al. 2012a).

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100
No, this species does not occur near waters connected to the Great Lakes basin and/or is not mobile or able to be transported by wind or water.	0 √
Unknown	U

- Calanipeda aquaedulcis *has not yet been identified in North or South America (Svetlichny et al. 2012b).*

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0 √
Unknown	U

- *There is no evidence that* C. aquaedulcis *has been found attached to recreational gear.*

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a) Is this species sold at aquarium/pet/garden stores ("brick & mortar" or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100
No, this species this species is rarely/never sold.	0 √
Unknown	U

- *After searching different commercial stores, nothing was found on the sale of* C. aquaedulcis.

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0 √
Unknown	U

- *Nothing found on stocking of* C. aquaedulcis.

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is likely to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces), this activity may occur within 20 km of the basin because of the species' popularity/value.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes	100

region.	
No, this species is not commercially cultured in or transported through the Great Lakes region.	0 √
Unknown	U

- *There was no evidence showing that* C. aquaedulcis is *commercially cultured or transported through the Great Lakes region.*

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80 √
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40
No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0
Unknown	U

- *Since* C. aquaedulcis *produces resting eggs, it would not be affected heavily by salinity increases during ballast exchange (Frisch et al. 2006, Svetlichny et al. 2012b), but it could potentially be flushed.*
- *It has the potential to survive ballast water exchange due to its high adaptability.* Calanipeda aquaedulcis *is an osmo-conformer that can survive at varying salinity levels (Svetlichny et al. 2012a).*
- Calanipeda aquaedulcis *likely entered the Bilbao estuary, along with other copepods, through the transport of ballast water (Albaina et al. 2009).*

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5 √
Yes, but this species has neither been observed in ballast/fouling ships entering the Great Lakes nor in ports in direct trade with the Great Lakes.	Score x 0.1
No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0
Unknown	U

- *While there is no direct shipping between the Great Lakes and the Ponto-Caspian (USEPA 2008), where* C. aquaedulcis *is native, this species is also found in Europe (Morocco, Spain, Mediterranean coastal areas), Russia, and North Africa.*
- Calanipeda aquaedulcis *is found in the Caspian Sea basin (including reservoirs of the Dnieper, Don, and Volga rivers) and Mediterranean; it is reported from Mallorca, Minorca, Camargue (France), Corsica, Sardinia, Sicily, North Africa (Morocco, Algeria, Tunisia), Portugal, Turkey, and Ukraine (Boxshall and Defaye 2009).*
- *It is also found in Italy, including in Lake Lesina (Lesina Lagoon) on the Adriatic Sea coast (Brugnano et al. 2011).*
- Calanipeda aquaedulcis *invaded the Aral Sea in the 1960s (Mirabdullayev et al. 2004) and the Bilbao estuary, Spain in 2001 (Albaina et al. 2009).*
- *The USEPA (2008) identified in their report the risk of invasion of this species from established populations in the Baltic Sea basin.*

Vector Potential Scorecard					
Vector		**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind		**0**	x	**0**	Unlikely
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.		**0**	x	**0**	Unlikely
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)		**0**	x	**0**	Unlikely
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)		**0**	x	**0**	Unlikely
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)		**0**	x	**0**	Unlikely
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling		**80**	x 0.5	**40**	Moderate
Total Unknowns (U)	**0**	**Confidence Level**		High	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

ESTABLISHMENT POTENTIAL RESULTS

Status: Not currently established in North America, including the Great Lakes

***Calanipeda aquaedulcis* has a moderate probability of establishment if introduced to the Great Lakes (Confidence level: High)**

The native range of *Calanipeda aquaedulcis* has similar climatic and abiotic conditions to that of the Great Lakes (Grigorovich et al. 2003, Reid and Orlova 2002, USEPA 2008). *Calanipeda aquaedulcis* is found in the Mediterranean coastal areas of Europe, which has summers similar to the Great Lakes, and the Azov Sea, which has winters as cold as those in the Great Lakes (Svetlichny et al. 2012b). *Calanipeda aquaedulcis* can tolerate a broad range of temperatures, oxygen levels, and salinities. Due to its ability to thrive in low temperatures and tolerate low oxygen levels, it is likely that *Calanipeda aquaedulcis* is able to overwinter in the Great Lakes basin if introduced. This species can adapt rapidly to fresh and salt water environments due to its osmo-independent metabolism (Svetlichny et al. 2012b). Increased salinization attributed to climate change may render the Great Lakes more suitable for this estuarine species (Brucet et al. 2008). It is found primarily in ogliotrophic waters, but can survive in eutrophic environments (Saygi et al. 2011, Svetlichny et al. 2012b). It has established in Lesina Lagoon, Italy, which experiences many of the same pollution issues that affects the Great Lakes (agricultural, wastewater treatment plants, watershed resident populations (Brugnano et al. 2011).

Due to its flexible, omnivorous diet, it is likely that *Calanipeda aquaedulcis* will find a suitable food source if introduced to the Great Lakes (Brucet et al. 2008). *Calanipeda aquaedulcis* may be preyed on by freshwater fish; however, it is unlikely that these predators will specifically target *Calanipeda aquaedulcis*. *Calanipeda aquaedulcis* produces resting eggs that may be capable of overwintering in the Great Lakes (Frisch et al. 2006, Svetlichny et al. 2012b). The egg densities that this species produces may be larger than those produced in its native range due to the lower salinity of the Great Lakes. The discharge of resting eggs in ballast sediment is thought to be infrequent and moderate in size.

Calanipeda aquaedulcis has expanded outside its native range considerably. This species can rapidly establish a dominant population after introduction. Ten years after its introduction to the Aral Sea in the 1960s, *Calanipeda aquaedulcis* became one of the dominant zooplankton species and consequently eliminated other zooplankton (Mirabdullayev et al. 2004). However, this species disappeared from the region in 1997. It has been suggested that *Calanipeda aquaedulcis* was introduced to the Bilbao estuary through the transport of ballast water (Albaina et al. 2009). This species was established there in 2001.

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
	9

- Calanipeda aquaedulcis *can adapt rapidly to fresh and salt water environments and has an osmo- and oxygen-independent metabolism (Svetlichny et al. 2012b)*

- *This species was shown to have a broad pH and temperature tolerance (at least 3-30°C) (Frisch et al. 2006, Marques et al. 2008).*
- Calanipeda aquaedulcis *is found primarily in oligotrophic environments independent of light and oxygen levels, but it is also able to survive in eutrophic environments (Saygi et al. 2011, Svetlichny et al. 2012b).*

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9
Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
	8

- Calanipeda aquaedulcis *has been known to thrive during the winter periods and has little effects from oxygen levels (Brugnano et al. 2011).*
- Calanipeda aquaedulcis *has a temperature range of about 3-30˚C but prefers cooler temperatures (Frisch et al. 2006).*
- *As this species produces resting eggs, it is likely to survive harsh conditions.*
- *Due to the climatic similarities between the Great Lakes and Ponto-Caspian regions (Reid and Orlova 2002) this species most likely endures similar overwintering conditions in its native range.*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
	9

- Calanipeda aquaedulcis *was shown to have a diverse diet, having varying dietary habits at different stages of life and based on what is readily available (Brucet et al. 2008).*

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding	6

species in the Great Lakes)	
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	0
Unknown	U
	6

- *The introduction of* C. aquaedulcis *into the Aral Sea in the 1960s resulted in it being the dominant species and eliminating other zooplankton. However, in 1997, it disappeared (Mirabdullayev et al. 2004).*

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
	U

- Calanipeda aquaedulcis *ovisacs usually stay attached to the female until they are hatched, unless under stressful conditions (Frisch et al. 2006, Svetlichny et al. 2012b).*

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
	5

- *The reproductive strategy of these species involves more parental investment than related species.* Calanipeda aquaedulcis *females keep their eggs attached to them until they are hatched compared to other that having resting eggs (Svetlichny et al. 2012b).*

- *At 18 ppt salinity, the* C. aquaedulcis *had significantly higher egg density compared to the related species* Arctodiaptomus alinus. Calanipeda aquaedulcis *was not tested at near fresh water salinity but* A. salinus *increased egg density at lower salinities (Svetlichny et al. 2012a).*

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- Calanipeda aquaedulcis *can be found in the Mediterranean coastal areas of Europe, which experiences summers much like that of the Great Lakes, and in the Azov Sea, which has winters reaching temperatures as cold as those in the Great Lakes (Svetlichny et al. 2012b).*
- *The Ponto-Caspian (Caspian, Azov, and Black Seas) have similar climate and surface water temperature ranges as the Great Lakes (Grigorovich et al. 2003, Reid and Orlova 2002, USEPA 2008).*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- Calanipeda aquaedulcis *of the Lesina Lagoon in Italy experiences many of the same pollution issues as the Great Lakes (agricultural, wastewater treatment plants, watershed resident population) and many different natural disturbances. The zooplankton community is able to respond rapidly to a change in these conditions (Brugnano et al. 2011).*
- *Great Lakes underwent similar anthropogenic eutrophication as the Ponto-Caspian region (Reid and Orlova 2002). Surface water temperature is similar between the Great Lakes and Ponto-Caspian seas (Grigorovich et al. 2003, Reid and Orlova 2002, USEPA 2008).*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0
Unknown	U
	6

- Calanipeda aquaedulcis *is found primarily in oligotrophic environments independent of light and oxygen levels, but it is also able to survive in eutrophic environments (Saygi et al. 2011, Svetlichny et al. 2012b).*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0
Unknown	U
	9

- Calanipeda aquaedulcis *is commonly found in estuarine or brackish waters, making an increase in salinity a more suitable environment (Brucet et al. 2008).*
- *This species was shown to have a broad pH and temperature tolerance (Marques et al. 2008).*
- Calanipeda aquaedulcis *has a temperature range of about 3-30˚C but prefers the cooler temperatures (Frisch et al. 2006).*

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0

Unknown	U
	7

- Calanipeda aquaedulcis can *change dietary habitats throughout development based on what is available (Brucet et al. 2008).*

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Great Lakes and is not likely to be introduced	-80% total points (at end)
Unknown	U
	9

- Calanipeda aquaedulcis *shows no reliance on other species for reproduction or survival.*

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes)	6
Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0

Unknown	U
	0

- *No species has been shown to facilitate the development of this species.*

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0
Unknown	U
	-10%

- Calanipeda aquaedulcis *is a macroinvertebrate that could have a natural predator in the Great Lakes but would not specifically target this species since most freshwater fish feed on copepods (Saygi et al. 2011).*

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9
Frequent, moderate inocula	6
Frequent, small inocula OR infrequent, large inocula	3
Infrequent, small or moderate inocula	0
Unknown	U
	2

- *Discharge of resting eggs in sediment would likely be infrequent and moderate in size.*

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
	5

- Calanipeda aquaedulcis *invaded the Bilbao estuary in 2001 (Albaina et al. 2009) and also the Aral Sea in the 1960s (Mirabdullayev et al. 2004).*

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
	6

- Calanipeda aquaedulcis *was expected to enter the Bilbao estuary through the transport of ballast water (Albaina et al. 2009).*
- *The introduction of* C. aquaedulcis *into the Aral Sea in the 1960s resulted in it being the dominant species by 1970 (Mirabdullayev et al. 2004).*

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing the establishment and spread of this species)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent the establishment and/or spread of this species	0

Unknown	U
	0

Establishment Potential Scorecard				
Points	**Probability for Establishment**	A. Total Points (pre-adjustment)		97
>100	High	**Adjustments**		
		B. Critical species	A*(1- 0%)	97
51-99	Moderate	C. Natural enemy	B*(1- 0%)	87.3
		Control measures	C*(1- 0%)	87.3
0-50	Low	**Potential for Establishment**		Moderate
# of questions answered as “unable to determine”	**Confidence Level**			
0-1	High	Total # of questions unknown		1
2-5	Moderate			
6-9	Low	Confidence Level		High
>9	Very low			

Section C: Potential for Impact

IMPACT POTENTIAL RESULTS

Environmental: Unknown

Socio-Economic: Low

Beneficial: Low

Current research on the potential for environmental impacts to result from *Calanipeda aquaedulcis* if introduced to the Great Lakes is inadequate to support proper assessment

If *Calanipeda aquaedulcis* is established in the Great Lakes, it may outcompete native species for available resources. It became one of the dominant species in the zooplankton communities after establishing in the Aral Sea and Bilbao estuary (Albaina et al. 2009, Mirabdullayev et al. 2004). There is no evidence suggesting that *Calanipeda aquaedulcis* alters its habitat or exhibits toxic effects. It is unknown if *Calanipeda aquaedulcis* modifies the physical components of the ecosystem, alters predator-prey relationships, or affects native populations genetically.

There is little or no evidence to support that *Calanipeda aquaedulcis* has the potential for significant socio-economic impacts if introduced to the Great Lakes.

It has not been reported that *Calanipeda aquaedulcis* poses a threat to human health or water quality. There is no evidence that this species negatively impacts infrastructure, economic sectors, recreational activities and associated tourism, or the aesthetic appeal of the areas it inhabits.

There is little or no evidence to support that *Calanipeda aquaedulcis* has the potential for beneficial impacts if introduced to the Great Lakes.

It has not been indicated that *Calanipeda aquaedulcis* can be used for the control of other organisms or improving water quality. There is no evidence to suggest that this species is commercially, recreationally, or medically valuable. It does not have significant positive ecological impacts.

POTENTIAL ENVIRONMENTAL IMPACT

NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1
Not significantly	0 √
Unknown	U

- *There is no direct evidence of* C. aquaedulcis *having a toxic effect.*

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1 √
Not significantly	0
Unknown	U

- *When introduced in the Aral Sea in the 1960s, it became the dominant species by the 1970s (Mirabdullayev et al. 2004).*
- *It also became one of the dominant species in the Bilbao estuary after potential invasion through ballast water (Albaina et al. 2009).*

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in the food web)	6
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	1
Not significantly	0
Unknown	U √

- *There has been no evidence provided that* C. aquaedulcis *alters predator-prey relationships; however, by replacing other species during invasion, it may have unreported trophic impacts.*

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0
Unknown	U √

- *It is unknown whether* C. aquaedulcis *affects native populations genetically.*

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1
Not significantly	0 √
Unknown	U

- Calanipeda aquaedulcis *is not known to alter its habitat, as it is known as a conformer and can adapt to different habitats (Svetlichny et al. 2012a).*

E6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem	6

AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1
Not significantly	0
Unknown	U √

- *It is unknown if* C. aquaedulcis *alters the physical components of an ecosystem.*

Environmental Impact Total	**1**
Total Unknowns (U)	**3**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	Low
1	0	
0	≥2	**Unknown**
1	≥1	

POTENTIAL SOCIO-ECONOMIC IMPACT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1
Not significantly	0 √
Unknown	U

- *There is no indication that* C. aquaedulcis *poses a threat to human health.*

S2) Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1

Not significantly	0 √
Unknown	U

- *There is no indication that* C. aquaedulcis *causes damage to the infrastructure, but since it does not attach and is small in size, it can be inferred it would not cause significant damage.*

S3) Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0 √
Unknown	U

- Calanipeda aquaedulcis *is not known to alter the water quality positively or negatively.*

S4) Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

- Calanipeda aquaedulcis *does not cause a strong decrease in any species that would negatively affect an economic sector.*

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

- *There is no evidence that* C. aquaedulcis *would inhibit recreational activities.*

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

- *There is no impact reported for* C. aquaedulcis *on the aesthetic appeal of a habitat.*

Socio-Economic Impact Total	**0**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**Low**
1	0	
0	≥2	Unknown
1	≥1	

POTENTIAL BENEFICIAL EFFECT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular effect. An "Unknown" response is appropriate if the potential for a particular effect might be inferred but has not been explicitly reported or if there is an unresolved debate about a particular effect.

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1
Not significantly	0 √
Unknown	U

- *There is no record of this species as a control for other organisms.*

B2) Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?

Yes, it is economically important to at least one of these industries	6
Yes, but its economic contribution is small	1
Not significantly	0 √
Unknown	U

- *There is no indication that it is commercially valuable.*

B3) Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local communities and/or tourism	6

It is sometimes employed recreationally, but adds little value to local communities or tourism	1
Not significantly	0 √
Unknown	U

- *There is no indication that it is recreationally valuable.*

B4) Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR It is potentially important to medicine or research and is currently being or scheduled to be studied	1
Not significantly	0 √
Unknown	U

- *There is no indication that it has medicinal or research value.*

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1
Not significantly	0 √
Unknown	U

- *There is no indication that it removes toxins or pollutants from the water.*

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1
Not significantly	0 √
Unknown	U

- Calanipeda aquaedulcis *could potentially contribute to another food source in the food web since the majority of freshwater fish eat copepods.*

Beneficial Effect Total	**0**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**Low**
1	0	
0	≥2	Unknown
1	≥1	

Scientific Name: *Cyclops kolensis*
Lilljeborg, 1901

Common Name: Waterflea

Synonyms:

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: Unlikely

Hitchhiking/fouling: Unlikely

Unauthorized intentional release: Unlikely

Stocking/planting/escape from recreational culture: Unlikely

Escape from commercial culture: Unlikely

Transoceanic shipping: Moderate

***Cyclops kolensis* has a moderate probability of introduction to the Great Lakes (Confidence level: High).**

Potential pathway(s) of introduction: Transoceanic Shipping (ballast water)

Cyclops kolensis does not currently occur near waters connected to the Great Lakes basin. Although uncommon, aquarists sell *Cyclops* copepods as frozen fish food, but it is unlikely that this particular species, *Cyclops kolensis*, is sold.

Cyclops kolensis produces resting eggs that may be carried in ballast water or sediment and may survive overseas transport (Grigorovich et al. 2003, USEPA 2008, Wonham et al. 2005). They produce a large number of eggs (0.8 million eggs/m^2) that float at the surface of the water and sink slowly when disturbed (Rivier 1996).

This species occurs in ports that have direct trade connections with the Great Lakes (NBIC 2009). It inhabits areas from southern Sweden through Poland, and from Germany to Lake Baikal (Reed 1968). There is a second distribution belt from the Arctic coast of Eurasia to Alaska.

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or	100

able to be transported by wind or water.	
No, this species does not occur near waters connected to the Great Lakes basin and/or is not mobile or able to be transported by wind or water.	0 √
Unknown	U

- *There are no data found that states* Cyclops kolensis *occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water. Data show that this species occurs near the Ponto-Caspian region (Grigorovich et al. 2003) and around Alaska (Reed 1968).*

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0 √
Unknown	U

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a) Is this species sold at aquarium/pet/garden stores ("brick & mortar" or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100

No, this species this species is rarely/never sold.	0 √
Unknown	U

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0 √
Unknown	U

- *No data have been found about if this species is being stocked or planted to natural waters or outdoor water gardens around the Great Lakes region.*

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is likely to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces), this activity may occur within 20 km of the basin because of the species' popularity/value.	Score x 0.25
Unknown	U

- *No data have been found about if this species is being stocked or planted to natural waters or outdoor water gardens around the Great Lakes region.*

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100

No, this species is not commercially cultured in or transported through the Great Lakes region.	0 √
Unknown	U

- *No articles mention that this species is being commercially cultured.*

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U

- *There were no data found that state that* Cyclops kolensis *occurs near waters connected to the Great Lake basin. Data show that this species occurs near the Ponto-Caspian region (Grigorovich et al. 2003) and around Alaska (Reed 1968).*

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80 √
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40
No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0
Unknown	U

- *This Ponto-Caspian copepod was identified as having high probability of invasion if introduced to the Great Lakes via ballast water or sediment, where it may survive as a resting stage (Grigorovich et al. 2003, USEPA 2008, Wonham et al. 2005).*
- Cyclops kolensis *is a summer diapausing species (Frisch 2002).*
- Cyclops kolensis *eggs can reach densities of 0.8 million individuals/m^2. The eggs have a specific gravity close to water, and, when disturbed, remain at the water surface and sink slowly (Rivier 1996).*

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5 √
Yes, but this species has neither been observed in ballast/fouling ships entering the Great Lakes nor in ports in direct trade with the Great Lakes.	Score x 0.1
No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0
Unknown	U

- *This species inhabits areas from southern Sweden through Poland and Germany to Lake Baikal; there is a second distribution belt from the Arctic coast of Eurasia to Alaska (Reed 1968).*

Vector Potential Scorecard					
Vector		**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind		**0**	x	**0**	Unlikely
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.		**0**	x	**0**	Unlikely
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)		**0**	x	**0**	Unlikely
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)		**0**	x	**0**	Unlikely
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)		**0**	x	**0**	Unlikely
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling		**80**	x 0.5	**40**	Moderate
Total Unknowns (U)	**0**	**Confidence Level**		High	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

ESTABLISHMENT POTENTIAL RESULTS

Status: **Not established in North America, including the Great Lakes**

***Cyclops kolensis* has a moderate probability of establishment if introduced to the Great Lakes (Confidence level: High).**

The native and introduced ranges of *Cyclops kolensis* have similar climate and abiotic conditions to that of the Great Lakes (Grigorovich et al. 2003, Reid and Orlova 2002, USEPA 2008). *Cyclops kolensis* inhabits areas of similar latitudes to the Great Lakes; it occurs in southern Sweden through Poland, and Germany to Lake Baikal, and a second distribution belt from the Arctic coast of Eurasia to Alaska (Reed 1968). Due to the ability of this species to tolerate ice-covered waters, it is likely that it will be able to overwinter in the Great Lakes. *Cyclops kolensis* inhabits environments with similar anthropogenic stressors as the Great Lakes. This species thrives in eutrophic water bodies, so pollution in the Great Lakes may facilitate its establishment (Kozminski 1936). The abundance of its preferred prey, calanoid copepods, in the Great Lakes may further facilitate *Cyclops kolensis* establishment (Wickham 1995). Inoculations are likely to consist of small numbers of diapausing eggs.

This species has been documented at relatively high densities (400 individuals/m^2), at numbers greater than endemic copepods (Pislegina and Silow 2009). In Lake Baikal, it has been reported that *Cyclops kolensis* dominated zooplankton communities in some years, reaching 80-90% of the total zooplankton biomass (Mazepova 1998). Consequently, there was a decrease in the abundance of their preferred prey, *Epischura*.

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
	6

- Cyclops kolensis *thrives in eutrophic lakes and occurs sparingly in oligotrophic areas (Kozminski 1936).*
- *Temperature tolerance ranges from from ice-covered waters (Kozminski 1933) to temperatures of 18-20°C in the summer (Reed 1968).*

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9
Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6

Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
	8

- Cyclops kolensis *is a cold water species (Reed 1968).*
- *In Poland, maximum population density occurs under the ice during February and March (Kozminski 1933).*
- *This species congregates in almost oxygen-free waters of Lake Wigry, Poland in February and March (Kozminski 1936).*
- *Due to the climatic similarities between the Great Lakes and Ponto-Caspian regions (Reid and Orlova 2002) this species most likely endures similar overwintering conditions in its native range.*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
	3

- Cyclops kolensis *species is a small predator (e.g., feeds mainly on larvae of* Epischura*) (Mazepova 1998).*
- Cyclops kolensis *is known to be highly selective of prey (Adrian 1991).*
- Cyclops kolensis *prefers small prey over larger prey and is raptorial (Wickham 1995).*

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	0
Unknown	U
	5

- Cyclops kolensis *has been documented at relatively high densities (400 individuals/m^2), with higher densities than endemic copepods (Pislegina and Silow 2009).*
- *In the abundant years, 1946 and 1950,* Cyclops *reached 80–90% of the total biomass of the zooplankton (Mazepova 1998).*

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
	2

- Cyclops kolensis *is univoltine, with one brood per year which is released in multiple clutches. It has a clutch size mean of 20-30 eggs and can produce at least 5 clutches a year with about 8 days in between (Jamieson 2003).*
- Cyclops kolensis *has three generations a year (Mazepova 1998).*
- *A study by Phong et al. (2008) of six cyclopoid species (genus Mesocyclops) found a range of 2.6-10.3 clutches per mating event (with mode between 4-5 clutches/event). Total clutch size ranged from 51.7-117.*

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
	2

- Cyclops kolensis *requires sexual reproduction, but can produce resting eggs.*

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6

Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- Cyclops kolensisi *inhabits areas of similar latitudes to the Great Lakes, from southern Sweden through Poland and Germany to Lake Baikal and a second distribution belt from the Arctic coast of Eurasia to Alaska (Reed 1968).*
- Cyclops kolensis *is a Ponto-Caspian species. The Great Lakes and Ponto-Caspian region are climatically compatible, which is one of the attributing factors to the success of Ponto-Caspian species in the Great Lakes (Reid and Orlova 2002).*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- Cyclops kolensis *inhabits areas with similar anthropogenic stressors as the Great Lakes.*
- Cyclops kolensis *dwells in freshwater habitats and prefers lotic areas.*
- *Abiotic factors and climatic conditions in the Ponto-Caspian region are quite similar to the Great Lakes, making the region compatible (Grigorovich et al. 2003, Reid and Orlova 2002).*
- *Great Lakes underwent similar anthropogenic eutrophication as the Ponto-Caspian region (Reid and Orlova 2002). Surface water temperature is similar between the Great Lakes and Ponto-Caspian seas (Grigorovich et al. 2003, Reid and Orlova 2002, USEPA 2008).*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0
Unknown	U
	7

- Cyclops kolensis *is typical of the pelagic region of permanent lakes (Einsle 1996, Santer and Lampert 1995, Schubert 1986).*
- Cyclops kolensis *was shown to have a capacity for dispersal (Frisch 2002).*

- Cyclops kolensis *thrives in eutrophic lakes and occurs sparingly in oligotrophic areas (Kozminski 1936).*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0
Unknown	U
	4

- Cyclops kolensis *has mixed effects and will depend on lake and degree of warming:*
- *Species numbers have shown a positive correlation with temperature (from about 3.8°C to78°C) (Pislegina and Silow 2009).*
- Cyclops kolensis *gradually declined in long-term study of warming German waters, 2.58°C in April, from about 7.5°C to just over 10°C, and was functionally replaced by the larger cyclopoid* Cyclops vicinus *(Adrian and Deneke 1996).*
- Cyclops kolensis *reproduction ceases and diapauses begins at 12-15°C (Rivier 1996).*

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
	7

- Cyclops kolensis *consumes calanoid copepods, which are plentiful in the Great Lakes.*
- Cyclops kolensis *consumes ciliates and cladocerans (Wickham 1995).*

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Great Lakes and is not likely to be introduced	-80% total points (at end)
Unknown	U
	9

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes)	6
Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0
Unknown	U
	0

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0
Unknown	U
	-10%

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9
Frequent, moderate inocula	6
Frequent, small inocula OR infrequent, large inocula	3
Infrequent, small or moderate inocula	0
Unknown	U
	2

- *Inoculations are likely to consist of small numbers of diapausing eggs in ballast water or sediment.*

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0

Unknown	U
	3

- Cyclops kolensis *was shown to have a capacity for dispersal (Frisch 2002).*
- Cyclops kolensis *established in the European part of Russia (DAISIE 2008a).*

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
	2

- *No data on rate of spread were found, but* C. kolensis *dispersal has been documented (Frisch 2002).*
- Cyclops kolensis *is an active migrant from the northern water-bodies of Russia to the Volga reservoirs (Rivier 1996).*

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing the establishment and spread of this species)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent the establishment and/or spread of this species	0
Unknown	U
	0

Establishment Potential Scorecard			
Points	**Probability for Establishment**	A. Total Points (pre-adjustment)	76
>100	High	**Adjustments**	

		B. Critical species	A*(1 - 0%)	76
51-99	Moderate	C. Natural enemy	B*(1 - 10%)	68.4
		Control measures	C*(1 - 0%)	68.4
0-50	Low	**Potential for Establishment**		Moderate
# of questions answered as “unable to determine”	**Confidence Level**			
0-1	High	Total # of questions unknown		0
2-5	Moderate			
6-9	Low	Confidence Level		High
>9	Very low			

Section C: Potential for Impact

<u>IMPACT POTENTIAL RESULTS</u>

Environmental: Unknown

Socio-Economic: Low

Beneficial: Low

Current research on the potential for environmental impacts to result from *Cyclops kolensis* if introduced to the Great Lakes is inadequate to support proper assessment.

It has been reported that *Cyclops kolensis* can dominate zooplankton communities. In Lake Baikal, it reached 80-90% of the total zooplankton biomass during a couple of years (Mazepova 1998). *Cyclops kolensis* has the potential to reduce the abundance of its prey. As a consequence of their population growth, *Cyclops kolensis* reduced the abundance of their preferred prey, *Epischura*. It is possible that *Cyclops kolensis* may compete with other organisms that feed on *Epischura*. This species has been documented at relatively high densities (400 individuals/m^2), at numbers greater than endemic copepods (Pislegina and Silow 2009). As a prey item, *Cyclops kolensis* has the potential to alter trophic dynamics by providing a source of food for the juvenile ruffe, *Gymnocephalus cernua* (Rivier 1996).

Cyclops is also an intermediate host for the tapeworm *Diphyllobothrium*, which infects fish such as salmon (CDC 2013). It has not been reported that this particular species, *Cyclops kolensis*, is a host for this tapeworm.

There is little or no evidence to support that *Cyclops kolensis* has the potential for significant socio-economic impact if introduced to the Great Lakes.

Cyclops species are vectors of several parasites. Members of this genus are an intermediate host for *Dracunculus medinensis* (Guinea Worm) which affects humans who drink water contaminated with infected water fleas. In dracunculiasis, or Guinea Worm disease, female worms are liberated from the water fleas after digestion, and subsequently move through the person’s subcutaneous tissue, causing intense pain (WHO 2013). It eventually emerges through the skin, usually at the feet, producing oedema, a blister that will become an ulcer. Guinea Worm disease is accompanied by fever, nausea, and vomiting. *Cyclops* is also an intermediate host for the tapeworm *Diphyllobothrium*, which infects fish such as salmon (CDC 2013). Humans can be infected by ingesting undercooked fish. It is not known if this particular species *Cyclcops kolensis* is a vector for these diseases.

It has not been reported that *Cyclops kolensis* poses a threat to water quality. There is no evidence that this species negatively impacts infrastructure, economic sectors. There is no indication that *Cyclops kolensis* affects recreational activities and associated tourism, or the aesthetic appeal of the areas it inhabits.

There is little or no evidence to support that *Cyclops kolensis* has the potential for significant beneficial impacts if introduced to the Great Lakes.

It has not been indicated that *Cyclops kolensis* can be used for the control of other organisms or improving water quality. There is no evidence to suggest that this species is commercially, recreationally, or medically valuable. It does not have significant positive ecological impacts.

POTENTIAL ENVIRONMENTAL IMPACT

NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1 √
Not significantly	0
Unknown	U

- *This species is a vector of several parasites. The rate of infection is unknown.*
- Cyclops *species are an intermediate host for* Dracunculus medinensis *(Guinea worm). In dracunculiasis (Guinea worm disease), female worms move through the person's subcutaneous tissue, causing intense pain, and eventually emerge through the skin, usually at the feet, producing oedema, a blister and eventually an ulcer, accompanied by fever, nausea, and vomiting (WHO 2013).*
- *Copepods are intermediate host for the tapeworm* Diphyllobothrium*, which can infect fish (particularly salmon) and can be passed to humans through ingestion of undercooked fish. The resulting diphyllobothriasis can include diarrhea, abdominal pain, vomiting, weight loss, fatigue, constipation and discomfort (CDC 2013).*

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival,	1

fecundity) or decline of at least one native population	
Not significantly	0
Unknown	U √

- *While its competitive effects are unknown, this species has been documented at relatively high densities (400 individuals/m^2), with higher densities than endemic copepods (Pislegina and Silow 2009).*
- *In abundant years (1946 and 1950),* Cyclops *reached 80–90% of the total biomass of the zooplankton in Lake Baikal (Mazepova 1998).*

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in the food web)	6
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	1
Not significantly	0
Unknown	U √

- Cyclops kolensis *forms 0.9% of the net primary production in Lake Baikal (Mazepova 1998). It is also seen in other water basins (Odum 1968). Thus, it is unlikely to cause significant shifts in food webs.*
- Cyclops kolensis *is the major food source for juvenile ruffe,* Gymnocephalus cernua *(Rivier 1996).*

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0
Unknown	U √

- *No information was provided in located articles.*

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1
Not significantly	0

Unknown	U √

- *No information was provided in located articles.*

E6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1
Not significantly	0
Unknown	U √

- *No information was provided in located articles.*

Environmental Impact Total	**1**
Total Unknowns (U)	**5**

<table>
<tr><th colspan="3">Scoring</th></tr>
<tr><th>Score</th><th># U</th><th>Impact</th></tr>
<tr><td>>5</td><td>Any</td><td>High</td></tr>
<tr><td>2-5</td><td>Any</td><td>Moderate</td></tr>
<tr><td>0</td><td>0-1</td><td rowspan="2">Low</td></tr>
<tr><td>1</td><td>0</td></tr>
<tr><td>0</td><td>≥2</td><td rowspan="2"><u>Unknown</u></td></tr>
<tr><td>1</td><td>≥1</td></tr>
</table>

<u>POTENTIAL SOCIO-ECONOMIC IMPACT</u>

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1

Not significantly	0
Unknown	U √

- Cyclops *species are an intermediate host for* Dracunculus medinensis *(Guinea worm). In dracunculiasis (Guinea worm disease), female worms move through the person's subcutaneous tissue, causing intense pain, and eventually emerge through the skin, usually at the feet, producing oedema, a blister and eventually an ulcer, accompanied by fever, nausea, and vomiting (WHO 2013).*
- *Copepods are intermediate host for the tapeworm* Diphyllobothrium*, which can infect fish (particularly salmon) and can be passed to humans through ingestion of undercooked fish. The resulting diphyllobothriasis can include diarrhea, abdominal pain, vomiting, weight loss, fatigue, constipation, and discomfort (CDC 2013) .*

S2) Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1
Not significantly	0 √
Unknown	U

S3) Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0 √
Unknown	U

- *No article mentioned how water quality might change if this species was introduced.*

S4) Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

- *No information was available.*

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

Socio-Economic Impact Total	**0**
Total Unknowns (U)	**1**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**<u>Low</u>**
1	0	
0	≥2	Unknown
1	≥1	

<u>POTENTIAL BENEFICIAL EFFECT</u>

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular effect. An "Unknown" response is appropriate if the potential for a particular effect might be inferred but has not been explicitly reported or if there is an unresolved debate about a particular effect.

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1
Not significantly	0 √
Unknown	U

- *No reports were found.*

B2) Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?

Yes, it is economically important to at least one of these industries	6
Yes, but its economic contribution is small	1
Not significantly	0 √
Unknown	U

B3) Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local communities and/or tourism	6
It is sometimes employed recreationally, but adds little value to local communities or tourism	1
Not significantly	0 √
Unknown	U

B4) Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR It is potentially important to medicine or research and is currently being or scheduled to be studied	1
Not significantly	0 √
Unknown	U

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1
Not significantly	0 √
Unknown	U

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1
Not significantly	0 √
Unknown	U

Beneficial Effect Total	**0**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**Low**
1	0	
0	≥2	Unknown
1	≥1	

Scientific Name: *Ectinosoma abrau*
Kritchagin, 1877

Common Name: Oarsman, Harpacticoid Copepod

Synonyms:

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: Unlikely

Hitchhiking/fouling: Unlikely

Unauthorized intentional release: Unlikely

Stocking/planting/escape from recreational culture: Unlikely

Escape from commercial culture: Unlikely

Transoceanic shipping: Low

***Ectinosoma abrau* has a low probability of introduction to the Great Lakes (Confidence level: High).**

Potential pathway(s) of introduction: Transoceanic Shipping (ballast water)

Ectinosoma abrau is occurs in the Black Sea and Azov Sea in eastern Europe, including Lake Ohrid of the Balkan peninsula, which drains into the Adriatic Sea and Lake Balaton (Grigorovich et al. 2003, Petkovski and Karanovic 1997). Ships originating in eastern Europe can potentially pick up this species and introduce it to the Great Lakes; however, this has not been observed (Grigorovich et al. 2003). *Ectinosoma abrau* produces resting stage eggs that are capable of surviving harsh conditions such as ballast water and sediment (Wonham et al. 2005). This species can tolerate salinities up to 30 ‰ (Aladin et al. 2008); *Ectinosoma abrau* is a marine organism so it is likely that it is capable of surviving overseas transport. *Ectinosoma abrau* does not currently occur in waters near the Great Lakes.

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100
No, this species does not occur near waters connected to the Great Lakes basin and/or is not mobile or able to be transported by wind or water.	0 √
Unknown	U

- Ectinsoma abrau *does not occur in waters near the Great Lakes; it is found in the Black Sea region of eastern Europe (Grigorovich et al. 2003).*

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0 √
Unknown	U

- Ectinosoma abrau *is found in eastern Europe (Grigorovich et al. 2003).*

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a) Is this species sold at aquarium/pet/garden stores ("brick & mortar" or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100
No, this species this species is rarely/never sold.	0 √
Unknown	U

- *This species is not known to be sold.*

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0 √
Unknown	U

- *This species is not known to be stocked or recreationally cultured.*

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is likely to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces), this activity may occur within 20 km of the basin because of the species' popularity/value.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100
No, this species is not commercially cultured in or transported through the Great Lakes region.	0 √
Unknown	U

- *This species is not known to be commercially cultured or transported in North America.*

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80 √
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40
No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0
Unknown	U

- *This species is listed as being capable of survival in ballast tanks (Grigorovich et al. 2003).*

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5
Yes, but this species has neither been observed in ballast/fouling ships entering the Great Lakes nor in ports in direct trade with the Great Lakes.	Score x 0.1 √
No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0
Unknown	U

- Ectinosoma abrau *is found in the Black and Azov Sea region of eastern Europe (Grigorovich et al. 2003), including Lake Ohrid on the Balkan peninsula (Petkovski and Karanovic 1997), which drains into the Adriatic Sea, and Lake Balaton.*
- Ectinosoma abrau *has the potential to be picked up by ships originating in eastern Europe; however it has not yet been observed in ships entering the Great Lakes (Grigorovich et al. 2003).*
- *In Moldova, including the Nistru River reservoirs Cuciurgan and Dubosari, Lake Cahul, Prut and Nistru lakes. Central, Western, steppes of Kazakhstan, Kyrgyzstan. (hydrobiologist.wordpress.com/tag/ectinosoma-abrau/)*

Vector Potential Scorecard				
Vector	**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind	**0**	x	**0**	Unlikely
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.	**0**	x	**0**	Unlikely
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)	**0**	x	**0**	Unlikely
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)	**0**	x	**0**	Unlikely
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)	**0**	x	**0**	Unlikely
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling	**80**	x 0.1	**8**	Low
Total Unknowns (U)	**0**	**Confidence Level**	High	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

ESTABLISHMENT POTENTIAL RESULTS

Status: **Not established in North America, including the Great Lakes**

***Ectinosoma abrau* has a low probability of establishment if introduced to the Great Lakes (Confidence level: Low).**

The native range of *Ectinosoma abrau* has similar climatic and abiotic conditions to that of the Great Lakes (Grigorovich et al. 2003, Reid and Orlova 2002, USEPA 2008). Although it is a marine species, it is able tolerate freshwater (Aladin et al. 2008).

There is not enough information on the diet of *Ectinosoma abrau*, the tolerance of *Ectinosoma abrau* to various environmental conditions, the fecundity of *Ectinosoma abrau*, and the previous invasion history of *Ectinosoma abrau* to fully predict its establishment to the Great Lakes basin. It is unknown how this species will respond to the effects of climate change in the Great Lakes. It is unknown how this species will interact with native species in the Great Lakes.

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
	6

- Ectinosoma abrau *is from the Black Sea region (Grigorovich et al. 2003).*
- *The Ponto-Caspian (Caspian, Azov, and Black seas) have similar climate and surface water temperature ranges as the Great Lakes (Grigorovich et al. 2003, Reid and Orlova 2002, USEPA 2008).*

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9
Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6

Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
	8

- *Due to the climatic similarities between the Great Lakes and Ponto-Caspian regions (Reid and Orlova 2002) this species most likely endures similar overwintering conditions in its native range.*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
	U

- *No Information was found on the diet of* E. abrau.

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	0
Unknown	U
	3

- *No information was found about the species' ability to outcompete native species, but as a copepod, it is unlikely to pose a major threat.*

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6

Moderate	3
Low	0
Unknown	U
	U

- *Information on the fecundity of* E. abrau *was not found.*

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
	0

- *Information on this species' reproductive strategy was not found, but it is unlikely to aid establishment.*

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- *The Great Lakes and Ponto-Caspian region are "climatically compatible," which is one of the attributing factors to the success of Ponto-Caspian species in the Great Lakes (Reid and Orlova 2002).*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- *Abiotic factors and climatic conditions of the native and introduced ranges of* E. abrau *are quite similar to the Great Lakes, making the region compatible (Grigorovich et al. 2003, Reid and Orlova 2002).*
- *Great Lakes underwent similar anthropogenic eutrophication as the Ponto-Caspian region (Reid and Orlova 2002). Surface water temperature is similar between the Great Lakes and Ponto-Caspian seas (Grigorovich et al. 2003, Reid and Orlova 2002, USEPA 2008).*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0
Unknown	U
	U

- *Little information was found on this subject.*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0
Unknown	U
	U

- *The adaptability of this species to climate change is unknown.*

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
	U

- *Information on this subject is unknown.*

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Great Lakes and is not likely to be introduced	-80% total points (at end)
Unknown	U
	9

- *No information on this subject could be found; from that it can be inferred that this species does not require other critical species.*

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in	9

the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes)	6
Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0
Unknown	U
	0

- *No information was found on this subject. It is unlikely that the establishment of this species will be aided by another species.*

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0
Unknown	U
	0

- *No natural predators of this species were found.*

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9
Frequent, moderate inocula	6
Frequent, small inocula OR infrequent, large inocula	3

Infrequent, small or moderate inocula	0
Unknown	U
	U

- *The size and frequency of potential introductions of this species are unknown.*

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
	U

- *No previous history of invasion has been found.*

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
	U

- *No information has been found regarding spread via human activities.*

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing the establishment and spread of this species)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used	-50% total points (at

to control its establishment and spread)	end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent the establishment and/or spread of this species	0
Unknown	U
	0

- *There are no control measures for this species.*

Establishment Potential Scorecard				
Points	**Probability for Establishment**	A. Total Points (pre-adjustment)		42
>100	High	**Adjustments**		
		B. Critical species	A*(1- 0%)	42
51-99	Moderate	C. Natural enemy	B*(1- 0%)	42
		Control measures	C*(1- 0%)	42
0-50	Low	**Potential for Establishment**		Low
# of questions answered as "unable to determine"	**Confidence Level**			
0-1	High	Total # of questions unknown		8
2-5	Moderate			
6-9	Low	Confidence Level		Low
>9	Very low			

Section C: Potential for Impact

IMPACT POTENTIAL RESULTS

Environmental: Unknown

Socio-Economic: Low

Beneficial: Low

Current research on the potential for environmental impacts to result from *Ectinosoma abrau* if introduced to the Great Lakes is inadequate to support proper assessment.

There is insufficient available information to determine whether *Ectinosoma abrau* poses a threat to other species or water quality. There are no reports that on how it affects or interacts with other species.

There is little or no evidence to support that *Ectinosoma abrau* has the potential for significant socio-economic impact if introduced to the Great Lakes.

It has not been reported that *Ectinosoma abrau* poses a threat to human health or water quality. There is no evidence that this species negatively impacts infrastructure, economic sectors, recreational activities and associated tourism, or the aesthetic appeal of the areas it inhabits.

There is little or no evidence to support that *Ectinosoma abrau* has the potential for significant beneficial impacts if introduced to the Great Lakes.

It has not been indicated that *Ectinosoma abrau* can be used for the control of other organisms or improving water quality. There is no evidence to suggest that this species is commercially, recreationally, or medically valuable. It does not have significant positive ecological impacts.

POTENTIAL ENVIRONMENTAL IMPACT

NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1
Not significantly	0
Unknown	U √

- *No information was found on whether* E. abrau *is a threat to the health of native species.*

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1
Not significantly	0
Unknown	U √

- *Information on species competition was not found.*

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in the food web)	6
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	1
Not significantly	0
Unknown	U √

- *Information on predator prey relationships was not found.*

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0
Unknown	U √

- *Information on whether or not this species has affected any native population genetically was not found.*

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1
Not significantly	0
Unknown	U √

- *Information about this species' effect on water quality was not found on this subject.*

E6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR	6

Yes, and it has resulted in significant negative consequences for at least one native species	
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1
Not significantly	0
Unknown	U √

- *Information about this species' effect on the physical ecosystem was not found.*

Environmental Impact Total	**0**
Total Unknowns (U)	**6**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	Low
1	0	
0	≥2	**Unknown**
1	≥1	

POTENTIAL SOCIO-ECONOMIC IMPACT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1
Not significantly	0 √
Unknown	U

- *No information on threats posed to human health was found.*

S2) Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1

Not significantly	0 √
Unknown	U

- *No information on damage to infrastructure caused by this species was found.*

S3) Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0 √
Unknown	U

- *No information on this species' effect on water quality was found.*

S4) Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

- *No information on this species' effect on commercial markets was found.*

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

- *No information on this species' effect on recreational activities was found.*

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

- *No information on this species' effect on the natural value or aesthetics of an area was found.*

Socio-Economic Impact Total	**0**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**Low**
1	0	
0	≥2	Unknown
1	≥1	

POTENTIAL BENEFICIAL EFFECT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular effect. An "Unknown" response is appropriate if the potential for a particular effect might be inferred but has not been explicitly reported or if there is an unresolved debate about a particular effect.

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1
Not significantly	0 √
Unknown	U

- *Information on if it is possible for this species can act as a biological control agent was not found.*

B2) Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?

Yes, it is economically important to at least one of these industries	6
Yes, but its economic contribution is small	1
Not significantly	0 √
Unknown	U

- *It is not known to be a commercially valuable species.*

B3) Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local	6

communities and/or tourism	
It is sometimes employed recreationally, but adds little value to local communities or tourism	1
Not significantly	0 √
Unknown	U

- *It is not known to be a recreationally valuable species.*

B4) Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR It is potentially important to medicine or research and is currently being or scheduled to be studied	1
Not significantly	0 √
Unknown	U

- *This species is not known to have medicinal or research value.*

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1
Not significantly	0 √
Unknown	U

- *No information was found on whether this species can improve water quality.*

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1
Not significantly	0 √
Unknown	U

- *No information on this species' ability to have a positive ecological effect was found.*

Beneficial Effect Total	**0**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**Low**
1	0	
0	≥2	Unknown
1	≥1	

Scientific Name: *Heterocope appendiculata*
G.O. Sars, 1863

Common Name: Oarsman, Calanoid Copepod

Synonyms:

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: Unlikely

Hitchhiking/fouling: Unlikely

Unauthorized intentional release: Unlikely

Stocking/planting/escape from recreational culture: Unlikely

Escape from commercial culture: Unlikely

Transoceanic shipping: Moderate

***Heterocope appendiculata* has a moderate probability of introduction to the Great Lakes (Confidence level: High).**

Potential pathway(s) of introduction: Transoceanic Shipping (ballast water)

It is predicted that *Heterocope appendiculata* will be introduced to the Great Lakes via ballast water (USEPA 2008, Wonham et al. 2005). *Heterocope appendiculata* individuals and eggs can be taken up by the ballast of both Ballast on Board (BOB) and No Ballast on Board (NOBOB) vessels (Wonham et al. 2005). Adults produce resting stages that may be able to survive the harsh ballast tank environments. *Heterocope appendiculata* may be introduced to the Great Lakes via ships declaring "No Ballast on Board" (NOBOB), which are exempt from ballast water exchange. The majority of ships entering the Great Lakes are NOBOB vessels and 43% of these ships contain residual water with less than 10‰ salinity (Johengen et al. 2005). In the study, the temperature of the residual water from the vessels sampled ranged from -0.7 to 23.9°C; thus, *Heterocope appendiculata* is likely to survive the salinity and temperature of the NOBOB ballast water. *Heterocope appendiculata* is established in the Baltic Sea basin, which contains ports in direct trade with the Great Lakes (NBIC 2009, USEPA 2008).

Heterocope appendiculata does not currently occur near waters connected to the Great Lakes basin. This species is not known to hitchhike or foul recreational gear. It is not cultured, stocked, or sold in the Great Lakes region.

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100
No, this species does not occur near waters connected to the Great Lakes basin and/or is not mobile or able to be transported by wind or water.	0 √
Unknown	U

- *Although the species* Heterocope appendiculata *is under high risk for invading the Great Lakes (Grigorovich et al. 2003), this organism has not been reported from North America.*

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0 √
Unknown	U

- *This species is not known to be present in North America.*

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a) Is this species sold at aquarium/pet/garden stores ("brick & mortar" or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100
No, this species this species is rarely/never sold.	0 √
Unknown	U

- *This species is not known to be sold.*

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0 √
Unknown	U

- *This species is a copepod and is not known to be stocked or recreationally cultured.*

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is <u>likely</u> to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces), this activity <u>may</u> occur within 20 km of the basin because of the species' popularity/value.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100
No, this species is not commercially cultured in or transported through the Great Lakes region.	0 √
Unknown	U

- *This species is a copepod and is not known to be commercially cultured or transported in North America.*

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80 √
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40
No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0
Unknown	U

- *Copepods were commonly reported in ballast and predicted to invade new water bodies; although resting eggs have been collected frequently from ballast sediments, few have been identified to species (Wonham et al. 2005).*

- Heterocope appendiculata *is known to be distributed through ballast water. Vessels may enter the Great Lakes carrying residual ballast water and sediment that contain viable organisms (Wonham et al. 2005).*
- *This species can be transported by no ballast on board ships, which present a larger risk of ballast-mediated invasions due to high trade into the Great Lakes (Grigorovich et al. 2003).*

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5 √
Yes, but this species has neither been observed in ballast/fouling ships entering the Great Lakes nor in ports in direct trade with the Great Lakes.	Score x 0.1
No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0
Unknown	U

- Heterocope appendiculata *is widely distributed in the southern part of Norway, in central Sweden, and in Finland from the Baltic Sea basin (GBIF 2010, Wesenberg-Lund 1908).*

Vector Potential Scorecard				
Vector	**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind	**0**	x	**0**	Unlikely
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.	**0**	x	**0**	Unlikely
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)	**0**	x	**0**	Unlikely
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)	**0**	x	**0**	Unlikely
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)	**0**	x	**0**	Unlikely
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling	**80**	x **0.5**	**40**	Moderate
Total Unknowns (U)	**0**	**Confidence Level**	High	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

ESTABLISHMENT POTENTIAL RESULTS

Status: **Not established in North America, including the Great Lakes**

Heterocope appendiculata **has a moderate probability of establishment if introduced to the Great Lakes (Confidence level: Moderate).**

The native and introduced ranges of *Heterocope appendiculata* have similar climatic and abiotic conditions as the Great Lakes (Grigorovich et al. 2003, Reid and Orlova 2002, USEPA 2008). *Heterocope appendiculata* inhabits the pelagic and littoral zone of large, deep lakes (Samchyshyna 2008, Walseng et al. 2006); there are abundant habitats suitable for this species in the Great Lakes. *Heterocope appendiculata* has a moderately broad physiological tolerance. This species can tolerate a somewhat wide range of water temperatures, oxygen levels, and pH. This species occurs in the Baltic Sea, which has a salinity range of 1-8 ppt (Reid and Orlova 2002). High nutrient conditions are not favorable for this species; 3 years after the fertilization of a lake, its biomass declined considerably (Langeland and Reinertsen 1982). *Heterocope appendiculata* overwinters as resting eggs in sub-arctic lakes (Persson and Vrede 2006) and occurs in waters that have temperatures under 5°, so it is somewhat likely that this species can overwinter in the Great Lakes. It is unknown if climate change will impact this species' establishment in the Great Lakes.

Heterocope appendiculata is carnivorous and raptorial. It primarily feeds on protozoa, rotifers, and small crustaceans, but feeds on phytoplankton as well (Persson and Vrede 2006); these prey types are available in the Great Lakes. Little is known about the competitive abilities and fecundity of *Heterocope appendiculata*.

This species has established somewhat extensively outside its native range, but its distribution is still restricted to central and eastern Europe. Glacial boundaries are thought to delimit the European distribution of *Heterocope appendiculata* (Engman 1994). *Heterocope appendiculata* is native to the Ponto-Caspian basin, and is thought to have spread up the Volga River and to the Baltic Sea basin (Slynko et al. 2002). It had spread into the Kuybyshev Reservoir in 1957 and the Oka River after 2000 (Tockner et al. 2009). The spread of this species may have been facilitated by the impoundment of reservoirs. After the impoundment of the Uglich and Ivankova reservoirs, specimens of *Heterocope appendiculata* were collected (Slynko et al. 2002). About 5 years after the impoundment of the Rybinsk

Reservoir, *Heterocope appendiculata* and other zooplankton invaders developed large populations. This species is now one of the most abundant zooplankton species in the Kama River (Tockner et al. 2009).

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
	6

- Heterocope appendiculata *can be found in the Baltic Sea, where the temperature ranges from 0-20°C, which is similar to the temperature in the Great Lakes (0.2-25.5°C). The salinity range in the Baltic Sea is 1-8 ppt and < 0.2 ppt in the Great Lakes (Reid and Orlova 2002).*
- Heterocope appendiculata *can survive between 3-23°C, but its optimal temperature tolerance (based on maximum abundance) is approximately 17°C (Bertilsson et al. 1995).*

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9
Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
	8

- Heterocope *overwinter as resting eggs in oligotrophic sub-arctic lakes and therefore does not need to store fatty acids as energy reserves (Persson and Vrede 2006).*
- *Due to the climatic similarities between the Great Lakes and Ponto-Caspian regions (Reid and Orlova 2002) this species most likely endures similar overwintering conditions in its native range.*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6

This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
	6

- Heterocope *are primarily carnivorous raptorial feeders—mainly on protozoa, rotifers, and small crustaceans, but phytoplankton may constitute a substantial fraction of their diets (Persson and Vrede 2006).*

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	0
Unknown	U
	U

- *The competitive abilities of* H. appendiculata *are not known.*

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
	U

- *The fecundity of this species is unknown, although in general, copepods reproduce sexually (Engman 1994).*

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	9

Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
	0

- *The reproductive strategy of this species is not known to aid establishment in new environments.*

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- *The Baltic Sea and the Great Lakes share many similar climate characteristics (Knight 2008).*
- *The Great Lakes and Ponto-Caspian region are "climatically compatible," which is one of the attributing factors to the success of Ponto-Caspian species in the Great Lakes (Reid and Orlova 2002).*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- *Surface temperature in the Baltic Sea ranges from 0-20°C, which is similar to the surface temperature in the Great Lakes (0.2-25.5°C). The salinity ranges in the Baltic Sea range from 1-8 ppt and < 0.2 ppt in the Great Lakes (Reid and Orlova 2002).*

- *Abiotic factors and climatic conditions in the Ponto-Caspian region are quite similar to the Great Lakes, making the region compatible (Grigorovich et al. 2003, Reid and Orlova 2002).*
- *Great Lakes underwent similar anthropogenic eutrophication as the Ponto-Caspian region (Reid and Orlova 2002). Surface water temperature is similar between the Great Lakes and Ponto-Caspian seas (Grigorovich et al. 2003, Reid and Orlova 2002, USEPA 2008).*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0
Unknown	U
	8

- Heterocope appendiculata *lives in open water.*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0
Unknown	U
	U

- *The adaptability of this species to climate change is unknown.*

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that	3

may be considered potential food items—are abundant and/or search time is moderate to high)	
Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
	8

- Heterocope *mainly feeds on protozoa, rotifers, phytoplankton, and small crustaceans (Persson and Vrede 2006).*
- Heterocope *has predatory tendencies and feed on other zooplankton as well as algae. These predators cruise through the water, attack their prey with a pounce and grasp them with their first and second maxillae. If the capture attempt fails, the copepod may swim into a vertical loop and try again (Thorp and Covich 2001).*

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Great Lakes and is not likely to be introduced	-80% total points (at end)
Unknown	U
	9

- Heterocope appendiculata *requires no critical species.*

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes)	6

Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0
Unknown	U
	0

- *This species is unlikely to be aided by another species.*

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0
Unknown	U
	0

- Heterocope appendiculata *is unlikely to be prevented from establishment by a natural enemy present in the Great Lakes.*

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9
Frequent, moderate inocula	6
Frequent, small inocula OR infrequent, large inocula	3
Infrequent, small or moderate inocula	0
Unknown	U
	U

- *The size and frequency of potential introductions of this species are unknown.*

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
	5

- *Nonindigenous species with diapause stages,* Heterocope appendiculata *was predicted to invade from the Ponto-Caspian region (Wonham et al. 2005).*
- Heterocope appendiculata *was likely to be introduced to the Kuibyshev reservoir in 1957. Although this species' native region was northern Europe, through hydro technical construction,* H. appendiculata *was also found in the Volga and Dnieper reservoirs (Grigorovich et al. 2003).*
- Heterocope appendiculata *entered the upper basin of the Volga from downstream. Currently, it is likely to be found in the middle Volga. Zooplankton biomass is made up of mostly rotifer from May to June and Crustacea from July to September.* Heterocope appendiculata *is one of the most abundant zooplankters in the Volga, not only in near-shore areas but also in the main river channel (Tockner et al. 2009).*

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
	4

- *Initially,* Heterocope appendiculata *was represented by single specimens in the Volga River. In the northernmost reservoir (Rybinsk), conditions were more favorable. Between 1946-1948, the regular inflow of northern invaders to this body of water allowed for the development of large populations of* Heterocope appendiculata. *These new zooplankton species of northern origins formed the base of a new food chain for planktivorous fish (Leppäkoski et al. 2002).*

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing the establishment and spread of this species)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent the establishment and/or spread of this species	0
Unknown	U
	0

- *There are no control measures for this species.*

Establishment Potential Scorecard				
Points	**Probability for Establishment**	A. Total Points (pre-adjustment)		70
>100	High	**Adjustments**		
		B. Critical species	A*(1- 0%)	70
51-99	Moderate	C. Natural enemy	B*(1- 0%)	70
		Control measures	C*(1- 0%)	70
0-50	Low	**Potential for Establishment**		Moderate
# of questions answered as "unable to determine"	**Confidence Level**			
0-1	High	Total # of questions unknown		4
2-5	Moderate			
6-9	Low	Confidence Level		Moderate
>9	Very low			

Section C: Potential for Impact

IMPACT POTENTIAL RESULTS

Environmental: Unknown

Socio-Economic: Low

Beneficial: Low

Current research on the potential for environmental impacts to result from *Heterocope appenediculata* if introduced to the Great Lakes is inadequate to support proper assessment.

After its introduction to the Volga River basin, *Heterocope appendiculata* and other non-native zooplankton species may have formed the basis of a new food chain for planktivorous fish (Slynko et al. 2002); however, there is not enough evidence to suggest that *Heterocope appendiculata* will significantly alter the food web if introduced to the Great Lakes. There is insufficient information available to determine whether *Heterocope appendiculata* poses a threat to other species or water quality. There are no reports on how it affects or interacts with other species. It is unknown whether this species alters the physical components of the ecosystem.

There is little or no evidence to support that *Heterocope appendiculata* has the potential for significant socio-economic impacts if introduced to the Great Lakes.

It has not been reported that *Heterocope appendiculata* poses a threat to human health or water quality. There is no evidence that this species negatively impacts infrastructure, economic sectors, recreational activities and associated tourism, or the aesthetic appeal of the areas it inhabits.

There is little or no evidence to support that *Heterocope appendiculata* has the potential for significant beneficial impacts if introduced to the Great Lakes.

It has not been indicated that *Heterocope appendiculata* can be used for the control of other organisms or improving water quality. There is no evidence to suggest that this species is commercially, recreationally, or medically valuable. It does not have significant positive ecological impacts.

POTENTIAL ENVIRONMENTAL IMPACT

NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1
Not significantly	0
Unknown	U √

- *Hazardous characteristics of this species are unknown.*

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered	6

species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1
Not significantly	0
Unknown	U √

- *The competitive character of this species is unknown.*

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in the food web)	6
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	1
Not significantly	0
Unknown	U √

- *The food web influence of this species is unknown.*

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0
Unknown	U √

- *The potential for genetic effects from this species is unknown.*

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1
Not significantly	0
Unknown	U √

- *The ability of this species to affect water quality is unknown.*

E6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1
Not significantly	0
Unknown	U √

- *The ability of this species to alter the physical ecosystem is unknown.*

Environmental Impact Total	**0**
Total Unknowns (U)	**6**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	Low
1	0	Low
0	≥2	**Unknown**
1	≥1	**Unknown**

POTENTIAL SOCIO-ECONOMIC IMPACT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1
Not significantly	0 √
Unknown	U

- *There have been no reports of this species affecting human health.*

S2) Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1
Not significantly	0 √
Unknown	U

- *There have been no reports of this species causing damage to infrastructure.*

S3) Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0 √
Unknown	U

- *There have been no reports of this species affecting water quality.*

S4) Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

- *There have been no reports of this species affecting commercial markets.*

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

- *There have been no reports of this species inhibiting recreational activities.*

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's	6

value for future generations	
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

- *There have been no reports of this species to having affected the natural values of areas it inhabits.*

Socio-Economic Impact Total	**0**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**<u>Low</u>**
1	0	
0	≥2	Unknown
1	≥1	

<u>POTENTIAL BENEFICIAL EFFECT</u>

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular effect. An "Unknown" response is appropriate if the potential for a particular effect might be inferred but has not been explicitly reported or if there is an unresolved debate about a particular effect.

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1
Not significantly	0 √
Unknown	U

- *There have been no reports of this species acting as a control agent.*

B2) Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?

Yes, it is economically important to at least one of these industries	6
Yes, but its economic contribution is small	1
Not significantly	0 √

Unknown	U

- *There have been no reports of this species being commercially valuable.*

B3) Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local communities and/or tourism	6
It is sometimes employed recreationally, but adds little value to local communities or tourism	1
Not significantly	0 √
Unknown	U

- *There have been no reports of this species being recreationally valuable.*

B4) Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR It is potentially important to medicine or research and is currently being or scheduled to be studied	1
Not significantly	0 √
Unknown	U

- *There have been no reports of this species having medicinal or research value.*

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1
Not significantly	0 √
Unknown	U

- *There have been no reports of this species improving water quality.*

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1 √
Not significantly	0
Unknown	U

- *As part of the new zooplankton community in the Volga,* H. appendiculata *helped form the base of a new food chain for planktivorous fish (Leppäkoski et al. 2002).*

Beneficial Effect Total	**1**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**Low**
1	0	
0	≥2	Unknown
1	≥1	

Scientific Name: *Heterocope caspia*
G.O. Sars 1897

Common Name: Oarsman, Calanoid Copepod

Synonyms:

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: Unlikely

Hitchhiking/fouling: Unlikely

Unauthorized intentional release: Unlikely

Stocking/planting/escape from recreational culture: Unlikely

Escape from commercial culture: Unlikely

Transoceanic shipping: Moderate

***Heterocope caspia* has a modeate probability of introduction to the Great Lakes (Confidence level: High).**

Potential pathway(s) of introduction: Transoceanic Shipping

It is predicted that *Heterocope caspia* will be introduced to the Great Lakes via ballast water (USEPA 2008, Wonham et al. 2005). *Heterocope caspia* individuals and eggs can be taken up by the ballast of both Ballast on Board (BOB) and No Ballast on Board (NOBOB) vessels (Wonham et al. 2005). Adults produce resting stages that may be able to survive the harsh ballast tank environments. *Heterocope caspia* may be introduced to the Great Lakes via ships declaring "No Ballast on Board" (NOBOB), which are exempt from ballast water exchange. The majority of ships entering the Great Lakes are NOBOB vessels and 43% of these ships contain residual water with less than 10‰ salinity (Johengen et al. 2005). In the study, the temperature of the residual water from the vessels sampled ranged from -0.7 to 23.9°C; thus, *Heterocope caspia* is likely to survive the salinity and temperature of the NOBOB ballast water on some ships. *Heterocope caspia* is established in the Baltic Sea basin, which contains ports in direct trade with the Great Lakes (NBIC 2009, USEPA 2008). This species may be introduced to the Great Lakes via the Lake Ladoga-Neva estuary-Gulf of Finland corridor, a transoceanic route with ships travelling between the Gulf of Finland and the Great Lakes (Berg et al. 2002).

Heterocope caspia does not currently occur near waters connected to the Great Lakes basin. This species is not known to hitchhike or foul recreational gear. It is not cultured, stocked, or sold in the Great Lakes region.

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100
No, this species does not occur near waters connected to the Great Lakes basin and/or is not mobile or able to be transported by wind or water.	0 √
Unknown	U

- Heterocope caspia *is not found in North America.*
- Heterocope caspia *is a Caspian-complex copepod native to the Ponto-Caspian/Black Sea-Azov Sea coast and present in reservoirs of the Volga River (Berg et al. 2002, Ketelaars 2004).*
- Heterocope caspia *is naturalized in both the Kubyshev and Saratov reservoirs of the Volga River (Popov 2011). Beyond the Volga water transit zone,* H. caspia *is absent (Zonn et al. 2009).*
- Heterocope caspia *is found in the slightly brackish water of the Caspian Sea near the Volga estuary, as well as its middle and southern basins; Karabuga Bay, Turkey; and various places in the Asov Sea (Tollinger 1911).*
- Heterocope caspia *is one of the most widespread zooplankton species in the Don River (Sukhodolov et al. 2009).*
- *It is characteristic of the Gulf of Taganrog and the Kuchurgan inlet (Zenkevitch 1963).*
- Heterocope caspia *is present in the Black Sea (Moldoveanu and Timofte 2004) and inland waters of Romania (Demeter and Morrone 2009), including the Danube (Dunare/Dunaiskyi) Delta Biosphere Reserve and the Kyliiske Mouth and Dnipro River Delta wetlands in Ukraine (Stetsenko et al. 2000). It has been recorded as common in southern Ukraine (Samchyshyna 2011), with particularly large summer populations in Lake Cahul (Naberezhny 1984).*

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0 √
Unknown	U

- Heterocope caspia *is not found in North America, nor is it considered to be a fouling organism.*

- Heterocope caspia *is a Caspian-complex copepod native to the Ponto-Caspian/Black Sea-Azov Sea coast and present in reservoirs of the Volga River (Berg et al. 2002, Ketelaars 2004).*
- Heterocope caspia *is naturalized in both the Kubyshev and Saratov reservoirs of the Volga River (Popov 2011). Beyond the Volga water transit zone,* H. caspia *is absent (Zonn et al. 2009).*
- Heterocope caspia *is found in the slightly brackish water of the Caspian Sea near the Volga estuary, as well as its middle and southern basins; Karabuga Bay, Turkey; and various places in the Asov Sea (Tollinger 1911).*
- Heterocope caspia *is one of the most widespread zooplankton species in the Don River (Sukhodolov et al. 2009).*
- *It is characteristic of the Gulf of Taganrog and the Kuchurgan inlet (Zenkevitch 1963).*
- Heterocope caspia *is present in the Black Sea (Moldoveanu and Timofte 2004) and inland waters of Romania (Demeter and Morrone 2009), including the Danube (Dunare/Dunaiskyi) Delta Biosphere Reserve and the Kyliiske Mouth and Dnipro River Delta wetlands in Ukraine (Stetsenko et al. 2000). It has been recorded as common in southern Ukraine (Samchyshyna 2011), with particularly large summer populations in Lake Cahul (Naberezhny 1984).*

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a) Is this species sold at aquarium/pet/garden stores ("brick & mortar" or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100
No, this species this species is rarely/never sold.	0 √
Unknown	U

- *This species is not known to be sold.*

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0 √
Unknown	U

- *This species is not known to be stocked in the Great Lakes region, but it was unsuccessfully introduced to the Aral Sea in 1971 as part of efforts to strengthen pelagic trophic links (Aladin et al. 2008b, Plotnikov et al. 2012, Zonn et al. 2009).*

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is <u>likely</u> to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces), this activity <u>may</u> occur within 20 km of the basin because of the species' popularity/value.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100
No, this species is not commercially cultured in or transported through the Great Lakes region.	0 √
Unknown	U

- *There is no known commercial culture of this species in the Great Lakes region.*

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80 √
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40
No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0
Unknown	U

- Heterocope caspia *was identified as a candidate species for introduction to the Great Lakes via northward spread through the Lake Ladoga-Neva estuary-Gulf of Finland river/reservoir/canal system connecting the Ponto-Caspian and Baltic Sea basins; St. Petersburg harbor would be the likeliest source for ballast water uptake by Great Lakes-bound freighters (Berg et al. 2002).*
- *While some reports suggest this species is stenohaline (Zenkevitch 1963), others note it clearly as euryhaline (Marsh 1933). Maximum salinity tolerance has been reported at 10.8‰ (Naberezhny 1984). In the Sea of Azov, it is present from 1-10‰ (not measured below 1‰) (Zenkevitch 1963).*
- Heterocope caspia *produces resistant resting (diapausing) stages that are predicted to invade the Great Lakes via transport in the sediments of no ballast on board (NOBOB) vessels (Grigorovich et al. 2003, Wonham et al. 2005). Copepod eggs are frequently found in the sediments of ballast tanks but are less common than those of rotifers and cladocerans; however, identification of copepod eggs to species is rare (Wonham et al. 2005). Ballast water is therefore predicted to be a more likely pathway of copepod introduction to the Great Lakes, as they are more often found there than in ballast sediments (Wonham et al. 2005).*
- *Copepods tend to be slower growing and more starvation-resistant, and are therefore predicted to remain in high abundance even after two weeks in a ballast environment (Wonham et al. 2005).*

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5 √
Yes, but this species has neither been observed in ballast/fouling ships entering the Great Lakes nor in ports in direct trade with the Great Lakes.	Score x 0.1
No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0
Unknown	U

- Heterocope caspia *was identified as a candidate species for introduction to the Great Lakes via northward spread through the Lake Ladoga-Neva estuary-Gulf of Finland river/reservoir/canal system connecting the Ponto-Caspian and Baltic Sea basins; St. Petersburg harbor would be the likeliest source for ballast water uptake by Great Lakes-bound freighters (Berg et al. 2002).*

Vector Potential Scorecard				
Vector	**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind	**0**	x	**0**	Unlikely
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.	**0**	x	**0**	Unlikely
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)	**0**	x	**0**	Unlikely
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)	**0**	x	**0**	Unlikely
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)	**0**	x	**0**	Unlikely
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling	**80**	x 0.5	**40**	Moderate
Total Unknowns (U) **0**		**Confidence Level**	High	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

ESTABLISHMENT POTENTIAL RESULTS

Status: **Not established in North America, including the Great Lakes**

***Heterocope caspia* has a moderate probability of establishment if introduced to the Great Lakes (Confidence level: Moderate).**

The native and introduced ranges of *Heterocope caspia* have similar climatic and abiotic conditions as the Great Lakes (Grigorovich et al. 2003, Reid and Orlova 2002, USEPA 2008). *Heterocope caspia* inhabits the pelagic zone above the thermocline in the dimictic part of Caspian lakes (Dumont 1998); there are pelagic habitats suitable for this species in the Great Lakes. *Heterocope caspia* has a moderately broad physiological tolerance. This species can tolerate a somewhat wide range of salinity, water temperatures, and oxygen levels. *Heterocope caspia* produces resistant life stages (Grigorovich et al. 2003), so it is somewhat likely that this species can overwinter in the Great Lakes. Increased salinization and warmer water temperatures due to climate change may make the Great Lakes more habitable for *Heterocope caspia*.

Heterocope caspia is omnivorous. It primarily feeds smaller zooplankton and algae (Kling et al. 1992); these prey types are available in the Great Lakes. Little is known about the competitive abilities and fecundity of *Heterocope caspia*.

This species has established somewhat extensively outside its native range, but its distribution is still restricted to central and eastern Europe. *Heterocope caspia* is native to the Ponto-Caspian basin, and is thought to have spread up the Volga River after the construction of locks that removed the natural barriers such as rapids (Slynko et al. 2002). *Heterocope caspia* is numerous in the Kuybyshev reservoir during the summer. It has been recorded in the lower and middle Volga (Tockner et al. 2009). This species was introduced to the Aral Sea in 1971 in efforts to strengthen pelagic trophic links (Plotnikov et al. 2012)**.** It was also unsuccessfully introduced to the Volga foredelta in 1971, and resulted in the introduction of *Limnomysis brandti* and *Evande trigona* (Zonn et al. 2009).

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
	7

- *While some reports suggest this species is stenohaline (Zenkevitch 1963), others note it clearly as euryhaline (Marsh 1933). Maximum salinity tolerance has been reported at 10.8‰ (Naberezhny 1984). In the Sea of Azov, it is present from 1-10‰ (not measured below 1‰) (Zenkevitch 1963).*
- *It is found both in fresh and salt water, and some consider it to have originally been a saltwater form that gradually adapted to a freshwater environment (Marsh 1933).*
- *Copepods tend to be slower growing and starvation-resistant (Wonham et al. 2005).*
- Heterocope caspia *was found at depths ranging from 20-60 m in the Shah Deniz gas field off the Aspheron Peninsula (Caspian Sea), but only comprised roughly 0.2% of the copepod biomass (ERT 2000). Nutrients*

concentrations at these sites included 0.1 mg/l nitrite, <2-4.5 mg/l nitrate, <1.0 mg/l ammonia, and <0.05 mg/l phosphate, while pH was between 7.9-8.2, dissolved oxygen between 11.6-14.3 mg/l, turbidity between 0-1 NTU, salinity roughly 12 ppt, and temperature 12.3-22.7˚C (ERT 2000).
- Heterocope caspia *is a thermophilic stenothermic species, active only during the warmer parts of the year; as such, it forms diapausing eggs to survive through the winter (Samchyshyna 2008).*

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9
Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
	8

- Heterocope caspia *is a thermophilic stenothermic species, active only during the warmer parts of the year; as such, it forms diapausing eggs to survive through the winter (Samchyshyna 2008).*
- Heterocope caspia *is present in the Kyliiske Mouth wetland of Ukraine, where average turbidity levels are 325 g/m^3 (Stoilovskyi and Kivganov 1998).*
- *Due to the climatic similarities between the Great Lakes and Ponto-Caspian regions (Reid and Orlova 2002) this species most likely endures similar overwintering conditions in its native range.*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
	8

- Heterocope caspia *is both a predator and a suspension feeder (Popov 2012).*
- *As with a few other* Heterocope *species, the diet of* H. caspia *may shift under variable trophic conditions, and include algae, bacteria, detritus, cladoceran neonats, nauplii, copepodites, protozoans, and rotifers (Samchyshyna 2008).*

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9
Somewhat likely (This species is known to have superior competitive abilities, but there	6

are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	0
Unknown	U
	U

- *The competitive abilities of* H. caspia *are not known. However, it is often found in high abundances and is reported to be one of most important components of the summer zooplankton; in reservoirs of the Volga River, it occurs in average densities of 800 individuals/m^3 from May to September, peaking from July to August with up to 4000 individuals/m^3 (Popov 2011).*

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
	U

- *The fecundity of* H. caspia *is not known.*

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
	2

- Heterocope caspia *eggs, unlike in other species of this genus, hatch in egg sacs instead of in the water column (Naberezhny 1984).*

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- Heterocope caspia *is a Caspian-complex copepod native to the Ponto-Caspian/Black Sea-Azov Sea coast and present in reservoirs of the Volga River (Berg et al. 2002, Ketelaars 2004).*
    - *The Caspian Sea consists of three basins, with salinities ranging from 0.1‰ in the northern basin to 10-13‰ in the middle and southern basins (CEP 2004). Summer temperatures vary by 1-2˚C among the basins (24-28˚C); however, in winter, the northern basin freezes (0-0.5˚C surface water), while the southern basin remains 10-11˚C (CEP 2004, Shiganova et al. 2004).*
- Heterocope caspia *is one of the most widespread zooplankton species in the Don River (Sukhodolov et al. 2009).*
    - *The Don experiences a period of stable air temperatures <0˚C that lasts up to 110 days in the northern catchment but only 30 days in the southwest. Mean temperatures in January decrease from southwest to northeast from -2˚C to -12˚C, and with a minimum of -44˚C. Snow cover usually appears in early November (averaging ~30 cm deep) in the north and late December (averaging ~5–10 cm) in the southwest. Spring air temperatures range between 4 and 15˚C for 40–50 days in the north and 60–70 days in the southwest. Summer is hot and dry, beginning in mid-May for 140 days in the south and late May for 100 days in the northeast. The mean temperature in July reaches 20˚C in the northeast and 25–30˚C in the south, and with a maximum of 45˚C. Autumn typically lasts for 60–70 days with gradual decreases in mean air temperature from 15 to 0˚C.*
- Heterocope caspia *is present in the Black Sea (Moldoveanu and Timofte 2004) and inland waters of Romania (Demeter and Morrone 2009), including the Danube (Dunare/Dunaiskyi) Delta Biosphere Reserve and the Kyliiske Mouth and Dnipro River Delta wetlands in Ukraine (Stetsenko et al. 2000).*
    - *The Dnipro River Delta has a temperate continental climate that is droughty with a hot summer with rainstorms and a short, mild winter. Annual snow cover fluctuates from 0 to 40 days with frequent thaws. The period without frost is 180–210 days, and the average monthly temperature fluctuates from -2.5°C to 20°C (Stetsenko et al. 2000).*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0

Unknown	U
	8

- Heterocope caspia *is found in the slightly brackish water of the Caspian Sea near the Volga estuary, as well as its middle and southern basins; Karabuga Bay, Turkey; and various places in the Asov Sea (Tollinger 1911).*
- *The Caspian Sea consists of three basins, with salinities ranging from 0.1‰ in the northern basin to 10-13‰ in the middle and southern basins (CEP 2004). Summer temperatures vary by 1-2˚C among the basins (24-28˚C); however, in winter, the northern basin freezes (0-0.5˚C surface water), while the southern basin remains 10-11˚C (CEP 2004, Shiganova et al. 2004). Salinity ranges from 0.1‰ near the Volga and Ural River mouths to 10-11‰ near the Middle Caspian boundary, increasing to 13‰ in the southern basin (Shiganova et al. 2004).*
- *Heterocope caspia biomass in the Sea of Azov is at its peak (~200 mg/m^3) between 2 and 3‰ salinity, but is present from 1-10‰ (not measured below 1‰) (Zenkevitch 1963).*
- Heterocope caspia *is suggested by some to be more stenohaline than other northern Caspian copepods, avoiding both increases and decreases in salinity (Zenkevitch 1963), but others consider it to be euryhaline and originally a saltwater species that gradually adapted to a freshwater environment (Marsh 1933). As a Ponto-Caspian species,* H. caspia *develops optimally in brackish waters, but has successfully migrated into fresh waters (Samchyshyna 2008).*
- Heterocope caspia *is characteristic of the Gulf of Taganrog and the Kuchurgan inlet, which is characterized by very low salinity (0.5-2‰) (Zenkevitch 1963).*
- Heterocope caspia *was found at depths ranging from 20-60 m in the Shah Deniz gas field off the Aspheron Peninsula (Caspian Sea), but only comprised roughly 0.2% of the copepod biomass (ERT 2000). Nutrients concentrations at these sites included 0.1 mg/l nitrite, <2-4.5 mg/l nitrate, <1.0 mg/l ammonia, and <0.05 mg/l phosphate, while pH was between 7.9-8.2, dissolved oxygen between 11.6-14.3 mg/l, turbidity between 0-1 NTU, salinity roughly 12 ppt, and temperature 12.3-22.7˚C (ERT 2000).*
- Heterocope caspia *is present in the Kyliiske Mouth wetland of Ukraine (Stoilovskyi and Kivganov 1998). The Kyliiske Mouth wetland is characterized by average mineralization, oxygen within the limits of normal saturation (though sometimes deficient in winter and in abundance in summer), average turbidity of 325 g/m^3, and sharp salinity (typically 1.8‰) and temperature fluctuations, particularly in the near-mouth areas (Stoilovskyi and Kivganov 1998).*
- *Low pH appears to be a limiting factor for calanoid copepods, but further research is needed (Samchyshyna 2008).*
- *In general, calanoid copepods of Ukraine's inland waters (e.g., along the Azov and Black Sea coasts) exhibit wide ecological plasticity (Samchyshyna 2008).*
- Heterocope caspia *is one of the most widespread zooplankton species in the Don River, a river characterized as being mildly to heavily polluted (Sukhodolov et al. 2009).*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0
Unknown	U
	8

- Heterocope caspia *is a pelagic, open water species. As such, habitats in the Great Lakes are likely to be abundant.*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0
Unknown	U
	8

- *As a euryhaline species, increased salinity (to a point) is not likely to pose a difficulty for* H. caspia. *However,* H. caspia *was unsuccessfully introduced to the Aral Sea in 1971 as part of efforts to introduce species able to survive that lake's ever increasing salinity (Aladin et al. 2008b, Plotnikov et al. 2012, Zonn et al. 2009).*
- *In general, calanoid copepods of Ukraine's inland waters (e.g., along the Azov and Black Sea coasts) exhibit wide ecological plasticity (Samchyshyna 2008).*
- *Warmer temperatures are also likely to favor* H. caspia*, as it active only during the warmer parts of the year (Samchyshyna 2008).*

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
	9

- *As both a predator and a suspension feeder (Popov 2012), the diet of* H. caspia *may shift under variable trophic conditions, and include algae, bacteria, detritus, cladoceran neonats, nauplii, copepodites, protozoans, and rotifers (Samchyshyna 2008). This diet should be easily satisfied in the Great Lakes.*

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Great Lakes and is not likely to be introduced	-80% total points (at end)
Unknown	U
	9

- *No critical species is required by* H. caspia.

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes)	6
Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0
Unknown	U
	0

- *There is no species likely to facilitate the establishment of spread of* H. caspia *in the Great Lakes.*

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the	-80% total points (at end)

Great Lakes)	
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0
Unknown	U
	0

- *Adult calanoid copepods are preyed upon by age-1 freshwater, marine, and semi-anadromous fishes in Ukraine's nursery ponds, while juveniles and eggs form an important component of the diets of carnivorous cladocerans, cyclopoid copepods, mosquito larvae, and comb jellies (ctenophores) (Samchyshyna 2008).*
- Heterocope caspia *is a main food item for kilka fish in the Caspian Sea, but this copepod population has sharply declined (and in some cases may be locally extinct) due to predation by the invasive* Mnemiopsis leidyi *comb jelly (Shiganova et al. 2004).*
- *However, in the Great Lakes, there is unlikely to be a predator that preferentially targets this species.*

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9
Frequent, moderate inocula	6
Frequent, small inocula OR infrequent, large inocula	3
Infrequent, small or moderate inocula	0
Unknown	U
	U

- *Copepod eggs are frequently found in the sediments of ballast tanks but are less common than those of rotifers and cladocerans; however, identification of copepod eggs to species is rare (Wonham et al. 2005). As such, the propagule pressure of this species is unknown.*

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close	3

proximity to each other)	
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
	6

- Heterocope caspia *is recognized as an alien species in Europe outside of its native range. It is thought to have extended its range to Volga and Dnieper reservoirs via shipping traffic associated with 1960s and 1970s waterway construction projects which provided new habitats and promoted dispersal along a northern migration corridor; it was first found in the Kremenchug reservoir (of Dnieper) in 1962 (Grigorovich et al. 2003, Ketelaars 2004).*
- Heterocope caspia *is naturalized in both the Kubyshev and Saratov reservoirs of the Volga River (Popov 2011). Beyond the Volga water transit zone,* H. caspia *is absent (Zonn et al. 2009).*
- Heterocope caspia *was identified as a candidate species for introduction to the Great Lakes via northward spread through the Lake Ladoga-Neva estuary-Gulf of Finland river/reservoir/canal system connecting the Ponto-Caspian and Baltic Sea basins (Berg et al. 2002).*

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
	6

- Heterocope caspia *is recognized as an alien species in Europe outside of its native range. It is thought to have extended its range to Volga and Dnieper reservoirs via shipping traffic associated with 1960s and 1970s waterway construction projects which provided new habitats and promoted dispersal along a northern migration corridor; it was first found in the Kremenchug reservoir (of Dnieper) in 1962 (Grigorovich et al. 2003, Ketelaars 2004).*

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing the establishment and spread of this species)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent the establishment and/or spread of this species	0

Unknown	U
	0

- *There are no control measures for this species.*

Establishment Potential Scorecard				
Points	**Probability for Establishment**	A. Total Points (pre-adjustment)		87
>100	High	**Adjustments**		
		B. Critical species	A*(1- 0%)	87
51-99	Moderate	C. Natural enemy	B*(1- 0%)	87
		Control measures	C*(1- 0%)	87
0-50	Low	**Potential for Establishment**		Moderate
# of questions answered as "unable to determine"	**Confidence Level**			
0-1	High	Total # of questions unknown		3
2-5	Moderate			
6-9	Low	Confidence Level		Moderate
>9	Very low			

Section C: Potential for Impact

IMPACT POTENTIAL RESULTS

Environmental: Unknown

Socio-Economic: Low

Beneficial: Low

Current research on the potential for environmental impacts to result from *Heterocope caspia* if introduced to the Great Lakes is inadequate to support proper assessment.

There is insufficient information available to determine whether *Heterocope caspia* poses a threat to other species or water quality. There are no reports on how it affects or interacts with other species. It is unknown whether this species alters the physical components of the ecosystem.

There is little or no evidence to support that *Heterocope caspia* has the potential for significant socio-economic impacts if introduced to the Great Lakes.

It has not been reported that *Heterocope caspia* poses a threat to human health or water quality. There is no evidence that this species negatively impacts infrastructure, economic sectors, recreational activities and associated tourism, or the aesthetic appeal of the areas it inhabits.

There is little or no evidence to support that *Heterocope caspia* has the potential for significant beneficial impacts if introduced to the Great Lakes.

Heterocope caspia could potentially contribute as a food source for planktivorous fish, but it is unknown if they would be beneficial to species in the Great Lakes. It has not been indicated that *Heterocope caspia* can be used for the control of other organisms or improving water quality. There is no evidence to suggest that this species is commercially, recreationally, or medically valuable. It does not have significant positive ecological impacts.

POTENTIAL ENVIRONMENTAL IMPACT

NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1
Not significantly	0
Unknown	U √

- *Hazards to the health of native species associated with* H. caspia *are unknown.*

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1
Not significantly	0
Unknown	U √

- *This species' competitive characteristics have not been described.*

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of	6

one or more native populations, creation of a dead end or any other significant alteration in the food web)	
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	1
Not significantly	0
Unknown	U √

- *Adult calanoid copepods are preyed upon by age-1 freshwater, marine, and semi-anadromous fishes in Ukraine's nursery ponds, while juveniles and eggs form an important component of the diets of carnivorous cladocerans, cyclopoid copepods, mosquito larvae, and comb jellies (ctenophores) (Samchyshyna 2008).*
- *The effect of this on trophic relationships within the food web is not known.*

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0
Unknown	U √

- *The potential for genetic effects from this species is unknown.*

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1
Not significantly	0
Unknown	U √

- *The influence of this species on water quality is unknown.*

E6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting	1

adverse effects have been mild	
Not significantly	0
Unknown	U √

- *The influence of this species on the physical ecosystem is unknown.*

Environmental Impact Total	**0**
Total Unknowns (U)	**6**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	Low
1	0	
0	≥2	**Unknown**
1	≥1	

POTENTIAL SOCIO-ECONOMIC IMPACT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1
Not significantly	0 √
Unknown	U

- *There have been no reports of this species affecting human health.*

S2) Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1
Not significantly	0 √
Unknown	U

- *There have been no reports of this species causing damage to infrastructure.*

S3) Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0 √
Unknown	U

- *There have been no reports of this species affecting water quality.*

S4) Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

- *There have been no reports of this species affecting commercial markets.*

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

- *There have been no reports of this species inhibiting recreational activities.*

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

- *There have been no reports of this species to having affected the natural values of areas it inhabits.*

Socio-Economic Impact Total	**0**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**Low**
1	0	
0	≥2	Unknown
1	≥1	

POTENTIAL BENEFICIAL EFFECT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular effect. An "Unknown" response is appropriate if the potential for a particular effect might be inferred but has not been explicitly reported or if there is an unresolved debate about a particular effect.

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1
Not significantly	0 √
Unknown	U

- *There have been no reports of this species acting as a control agent.*

B2) Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?

Yes, it is economically important to at least one of these industries	6
Yes, but its economic contribution is small	1
Not significantly	0 √
Unknown	U

- *There have been no reports of this species being commercially valuable*

B3) Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local communities and/or tourism	6
It is sometimes employed recreationally, but adds little value to local communities or tourism	1
Not significantly	0 √

Unknown	U

- *There have been no reports of this species being recreationally valuable.*

B4) Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR It is potentially important to medicine or research and is currently being or scheduled to be studied	1
Not significantly	0 √
Unknown	U

- *There have been no reports of this species having medicinal or research value.*

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1
Not significantly	0 √
Unknown	U

- *There have been no reports of this species improving water quality.*

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1 √
Not significantly	0
Unknown	U

- *This species could potentially contribute to another food source in the food web since the majority of freshwater fish eat copepods.*
- *While unsuccessful,* H. caspia *was attempted to be introduced to the Aral Sea in 1971 as part of efforts to strengthen pelagic trophic links (Aladin et al. 2008b, Plotnikov et al. 2012, Zonn et al. 2009).*
- *Adult calanoid copepods are preyed upon by age-1 freshwater, marine, and semi-anadromous fishes in Ukraine's nursery ponds, while juveniles and eggs form an important component of the diets of carnivorous cladocerans, cyclopoid copepods, mosquito larvae, and comb jellies (ctenophores) (Samchyshyna 2008).*
- Heterocope caspia *is a main food item for kilka fish in the Caspian Sea (Shiganova et al. 2004).*
- *Copepod larvae, including that of* H. caspia*, have been recorded as playing a major role in the summer zooplankton community in the Sea of Azov, making up to 42% of the zooplankton biomass in June, with smaller numbers in the Gulf of Taganrog (Zenkevitch 1963).*

Beneficial Effect Total	**1**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**Low**
1	0	
0	≥2	Unknown
1	≥1	

Scientific Name: *Paraleptastacus spinicaudus triseta*
Noodt, 1954

Common Name: Oarsman, Harpacticoid Copepod

Synonyms: *Paraleptastacus spinicaudata triseta, Paraleptastacus spinicauda triseta*

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: Unlikely

Hitchhiking/fouling: Unlikely

Unauthorized intentional release: Unlikely

Stocking/planting/escape from recreational culture: Unlikely

Escape from commercial culture: Unlikely

Transoceanic shipping: Moderate

***Paraleptastacus spinicaudus triseta* has a moderate probability of introduction to the Great Lakes (Confidence level: High).**

Potential pathway(s) of introduction: Transoceanic Shipping (ballast water)

It is predicted that *Paraleptastacus spinicaudus triseta* will be introduced to the Great Lakes via ballast water (USEPA 2008, Wonham et al. 2005). *Paraleptastacus spinicaudus triseta* may be introduced to the Great Lakes via ships declaring "No Ballast on Board" (NOBOB) (Grigorovich et al. 2003), which are exempt from ballast water exchange. The majority of ships entering the Great Lakes are NOBOB vessels and 43% of these ships contain residual water with less than 10‰ salinity (Johengen et al. 2005). In the study, the temperature of the residual water from the vessels sampled ranged from -0.7 to 23.9°C; thus, *Paraleptastacus spinicaudus triseta* is likely to survive the salinity and temperature of the NOBOB ballast water of some ships. Adults are able to enter diapause and may survive anoxic ballast environments (Grigorovich et al. 2003). *Paraleptastacus spinicaudus* has been recorded in drifting algae collected in the Baltic Sea (Arroyo et al. 2006), a water body with ports in direct trade with the Great Lakes (NBIC 2009, USEPA 2008).

Paraleptastacus spinicaudus does not currently occur near waters connected to the Great Lakes basin. This species is not known to hitchhike or foul recreational gear. It is not cultured, stocked, or sold in the Great Lakes region.

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100
No, this species does not occur near waters connected to the Great Lakes basin and/or is not mobile or able to be transported by wind or water.	0 √
Unknown	U

- Paraleptastacus spinicaudus triseta *is from the Ponto-Caspian region of eastern Europe.*

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0 √
Unknown	U

- Paraleptastacus spinicaudus triseta *is found in eastern Europe*

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a) Is this species sold at aquarium/pet/garden stores ("brick & mortar" or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100
No, this species this species is rarely/never sold.	0 √
Unknown	U

- *This species is not known to be sold.*

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5
This species is not very popular or is not easily obtained within the Great Lakes *region*.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0 √
Unknown	U

- *This species is not known to be stocked or recreationally cultured.*

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is likely to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces), this activity may occur within 20 km of the basin because of the species' popularity/value.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100
No, this species is not commercially cultured in or transported through the Great Lakes region.	0 √
Unknown	U

- *This species is not known to be commercially cultured or transported in North America.*

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80 √
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40
No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0
Unknown	U

- *This species is listed as being capable of survival in no-ballast-on-board ships (Grigorovich et al. 2003).*

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5 √
Yes, but this species has neither been observed in ballast/fouling ships entering the Great Lakes nor in ports in direct trade with the Great Lakes.	Score x 0.1
No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0
Unknown	U

- *This species has the potential to be picked up by ships originating in eastern Europe; however it has not yet been observed in ships entering the Great Lakes (Grigorovich et al. 2003).*
- *This species has been recorded in Loch Fyne, along the western coast of Ireland (Nicholls 1935).*

Vector Potential Scorecard					
Vector		**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind		**0**	x	**0**	Unlikely
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.		**0**	x	**0**	Unlikely
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)		**0**	x	**0**	Unlikely
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)		**0**	x	**0**	Unlikely
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)		**0**	x	**0**	Unlikely
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling		**80**	x 0.5	**40**	Moderate
Total Unknowns (U)	**0**	**Confidence Level**		High	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low

0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

ESTABLISHMENT POTENTIAL RESULTS

Status: **Not established in North America, including the Great Lakes**

Paraleptastacus spinicaudus triseta **has a low probability of establishment if introduced to the Great Lakes (Confidence level: Low).**

The native and introduced ranges of *Paraleptastacus spinicaudus triseta* have similar climatic and abiotic conditions as the Great Lakes (Grigorovich et al. 2003, Reid and Orlova 2002, USEPA 2008). *Paraleptastacus spinicaudus* primarily inhabits sand and sediments of coastal marine and estuarine environments, but it has been introduced to inland fresh waters before (Alexandrov et al. 2007); there are habitats available for this species in the Great Lakes region. *Paraleptastacus spinicaudus* has a moderately broad physiological tolerance. This species can tolerate a somewhat wide range of salinity, water temperatures, and oxygen levels. As a coastal marine and estuarine organism, increased salinization and warmer water temperatures due to climate change may make the Great Lakes more habitable for *P. spinicaudus*.

Paraleptastacus spinicaudus feeds on bacteria (Cnudde 2013), so it is likely that this species will find an appropriate food source in the Great Lakes. Little is known about the competitive abilities and fecundity of *P. spinicaudus*.

This species has established extensively outside its native range, and occurs through much of Europe and on the coasts of British Columbia. The rate of its spread is unknown.

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3

Unknown	U
	6

- Paraleptastacus spinicaudus triseta *is predicted to be able to survive in the Great Lakes region (Grigorovich et al. 2003).*

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9
Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
	8

- *Due to the climatic similarities between the Great Lakes and Ponto-Caspian regions (Reid and Orlova 2002) this species most likely endures similar overwintering conditions in its native range.*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
	U

- *No information was found on the diet of* P. spinicaudus triseta.

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3
Unlikely (This species is known as a poor competitor that thrives only in environments	0

with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	
Unknown	U
	3

- *No information was found about the species' ability to outcompete native species, but as a copepod, it is unlikely to pose a major threat.*

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
	U

- *Information on the fecundity of* P. spinicaudus triseta *was not found.*

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
	0

- *Information on this species' reproductive strategy was not found, but it is unlikely to aid establishment.*

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9

Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- *Grigorovich et al. (2003) stated that conditions were similar enough to allow survival in the Great Lakes.*
- *The Great Lakes and Ponto-Caspian region are climatically compatible, which is one of the attributing factors to the success of Ponto-Caspian species in the Great Lakes (Reid and Orlova 2002).*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- *Abiotic factors and climatic conditions in the Ponto-Caspian region are quite similar to the Great Lakes, making the region compatible (Grigorovich et al. 2003, Reid and Orlova 2002).*
- *Great Lakes underwent similar anthropogenic eutrophication as the Ponto-Caspian region (Reid and Orlova 2002). Surface water temperature is similar between the Great Lakes and Ponto-Caspian seas (Grigorovich et al. 2003, Reid and Orlova 2002, USEPA 2008).*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0
Unknown	U
	U

- *Little information was found on this subject.*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0
Unknown	U
	U

- *The adaptability of this species to climate change is unknown.*

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
	U

- *Information on this subject is unknown.*

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	3

Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Great Lakes and is not likely to be introduced	-80% total points (at end)
Unknown	U
	9

- *No information on this subject could be found; from that it can be inferred that this species does not require other critical species.*

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes)	6
Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0
Unknown	U
	0

- *No information was found on this subject. It is unlikely that the establishment of this species will be aided by another species.*

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)

Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0
Unknown	U
	0

- *No natural predators of this species were found.*

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9
Frequent, moderate inocula	6
Frequent, small inocula OR infrequent, large inocula	3
Infrequent, small or moderate inocula	0
Unknown	U
	U

- *The size and frequency of potential introductions of this species are unknown.*

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
	U

- *No previous history of invasion has been found.*

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6

Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
	U

- *No information has been found regarding spread via human activities.*

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing the establishment and spread of this species)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent the establishment and/or spread of this species	0
Unknown	U
	0

- *There are no control measures for this species.*

Establishment Potential Scorecard				
Points	**Probability for Establishment**	A. Total Points (pre-adjustment)		42
>100	High	**Adjustments**		
		B. Critical species	A*(1- 0%)	42
51-99	Moderate	C. Natural enemy	B*(1- 0%)	42
		Control measures	C*(1- 0%)	42
0-50	Low	**Potential for Establishment**		Low
# of questions answered as "unable to determine"	**Confidence Level**			
0-1	High	Total # of questions unknown		8
2-5	Moderate			
6-9	Low	Confidence Level		Low
>9	Very low			

Section C: Potential for Impact

IMPACT POTENTIAL RESULTS

Environmental: Unknown

Socio-Economic: Low

Beneficial: Low

Current research on the potential for environmental impacts to result from *Paraleptastacus spinicaudus triseta* if introduced to the Great Lakes is inadequate to support proper assessment.

There is insufficient information available to determine whether *Paraleptastacus spinicaudus triseta* poses a threat to other species or water quality. There are no reports on how it affects or interacts with other species. It is unknown whether this species alters the physical components of the ecosystem.

There is little or no evidence to support that *Paraleptastacus spinicaudus triseta* has thepotential for significant socio-economic impacts if introduced to the Great Lakes.

It has not been reported that *Paraleptastacus spinicaudus triseta* poses a threat to human health or water quality. There is no evidence that this species negatively impacts infrastructure, economic sectors, recreational activities and associated tourism, or the aesthetic appeal of the areas it inhabits.

There is little or no evidence to support that *Paraleptastacus spinicaudus* has the potential for significant beneficial impacts if introduced to the Great Lakes.

It has not been indicated that *Paraleptastacus spinicaudus* can be used for the control of other organisms or improving water quality. There is no evidence to suggest that this species is commercially, recreationally, or medically valuable. It does not have significant positive ecological impacts.

POTENTIAL ENVIRONMENTAL IMPACT

NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1
Not significantly	0
Unknown	U √

- *No information was found on whether* P. spinicaudus triseta *is a threat to the health of native species.*

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1
Not significantly	0
Unknown	U √

- *Information on species competition was not found.*

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in the food web)	6
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	1
Not significantly	0
Unknown	U √

- *Information on predator prey relationships was not found.*

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0
Unknown	U √

- *Information on whether or not this species has affected any native population genetically was not found.*

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected water quality to some extent, but the alterations and resulting adverse	1

effects have been limited or inconsistent (as compared with above statement)	
Not significantly	0
Unknown	U √

- *Information about this species' effect on water quality was not found on this subject.*

E6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1
Not significantly	0
Unknown	U √

- *Information about this species' effect on the physical ecosystem was not found.*

Environmental Impact Total	**0**
Total Unknowns (U)	**6**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	Low
1	0	Low
0	≥2	**Unknown**
1	≥1	**Unknown**

POTENTIAL SOCIO-ECONOMIC IMPACT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1
Not significantly	0 √
Unknown	U

- *No information on threats posed to human health was found.*

S2) Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1
Not significantly	0 √
Unknown	U

- *No information on damage to infrastructure caused by this species was found.*

S3) Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0 √
Unknown	U

- *No information on this species' effect on water quality was found.*

S4) Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

- *No information on this species' effect on commercial markets was found.*

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

- *No information on this species' effect on recreational activities was found.*

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

- *No information on this species' effect on the natural value or aesthetics of an area was found.*

Socio-Economic Impact Total	**0**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**Low**
1	0	
0	≥2	Unknown
1	≥1	

POTENTIAL BENEFICIAL EFFECT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular effect. An "Unknown" response is appropriate if the potential for a particular effect might be inferred but has not been explicitly reported or if there is an unresolved debate about a particular effect.

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1
Not significantly	0 √
Unknown	U

- *Information on if it is possible for this species can act as a biological control agent was not found.*

B2) Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?

Yes, it is economically important to at least one of these industries	6
Yes, but its economic contribution is small	1
Not significantly	0 √
Unknown	U

- *It is not known to be a commercially valuable species.*

B3) Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local communities and/or tourism	6
It is sometimes employed recreationally, but adds little value to local communities or tourism	1
Not significantly	0 √
Unknown	U

- *It is not known to be a recreationally valuable species.*

B4) Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR It is potentially important to medicine or research and is currently being or scheduled to be studied	1
Not significantly	0 √
Unknown	U

- *This species is not known to have medicinal or research value.*

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1
Not significantly	0 √
Unknown	U

- *No information was found on whether this species can improve water quality.*

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1

Not significantly	0 √
Unknown	U

- *No information on this species' ability to have a positive ecological effect was found.*

Beneficial Effect Total	**0**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**Low**
1	0	
0	≥2	Unknown
1	≥1	

A.7 Crustaceans - Mysids

Scientific Name: *Limnomysis benedeni*
Czerniavsky, 1882

Common Name: Caspian Slender Mysid, Danube Mysid, Pontian Mysid

Synonyms:

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: Unlikely

Hitchhiking/fouling: Unlikely

Unauthorized intentional release: Unlikely

Stocking/planting/escape from recreational culture: Unlikely

Escape from commercial culture: Unlikely

Transoceanic shipping: Moderate

***Limnomysis benedeni* has a moderate probability of introduction to the Great Lakes (Confidence level: High).**

Potential pathway(s) of introduction: Transoceanic Shipping

Ricciardi and Rasmussen (1998) listed this species among five Ponto-Caspian mysids that, due to their salinity tolerance, are likely to be transported to the Great Lakes via ballast water. The related *Hemimysis anomala* fulfilled this prediction in 2006 (Pothoven et al. 2007). Grigorovich et al. (2003), however, identified *L. benedeni* as having a reduced probability of invasion due to the effects of ballast water exchange or flushing, while they classified *H. anomala* as having a greater likelihood of introduction. This species is currently widespread throughout the entire North Sea basin (lower Rhine River), Baltic Sea basin, and Black-Azov Sea basin (bij de Vaate et al. 2002, Grigorovich et al. 2003), all of which sustain heavy amounts of Great Lakes shipping traffic.

Ovcarenko et al. (2006) reported that *L. benedeni* was largely unaffected by salinity increases up to 19 PSU and showed only about 25% mortality when exposed to 23 PSU for 24 hours. It was not until 24 hours of exposure to 34 PSU that a 100% mortality rate was observed. This high salinity tolerance was confirmed by Santagata et al. (2008), who reported 60$\pm$14% and 55$\pm$13% (mean $\pm$ s.d.) survival rates for freshwater individuals exposed to full-strength (34 PSU) seawater for 48 hours in flow-through and empty-refill treatments, respectively. These results provide evidence that current ballast water control measures may not be completely effective in preventing the introduction of this species to the Great Lakes.

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100
No, this species does not occur near waters connected to the Great Lakes basin and/or is not mobile or able to be transported by wind or water.	0 √
Unknown	U

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0 √
Unknown	U

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a) Is this species sold at aquarium/pet/garden stores ("brick & mortar" or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100
No, this species this species is rarely/never sold.	0 √
Unknown	U

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0 √
Unknown	U

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is <u>likely</u> to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces), this activity <u>may</u> occur within 20 km of the basin because of the species' popularity/value.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100
No, this species is not commercially cultured in or transported through the Great Lakes region.	0 √
Unknown	U

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80 √
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40
No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0
Unknown	U

- *Ricciardi and Rasmussen (1998) listed this species among five Ponto-Caspian mysids that, due to their salinity tolerance, are likely to be transported to the Great Lakes via ballast water. The related* Hemimysis anomala *fulfilled this prediction in 2006 (Pothoven et al. 2007).*
- *Grigorovich et al. (2003), however, identified* L. benedeni *as having a reduced probability of invasion due to the effects of ballast water exchange or flushing, while they classified* H. anomala *as having a greater likelihood of introduction.*

- *Ovcarenko et al. (2006) reported that* L. benedeni *was largely unaffected by salinity increases up to 19 PSU and showed only about 25% mortality when exposed to 23 PSU for 24 hours. It was not until 24 hours of exposure to 34 PSU that a 100% mortality rate was observed.*
- *This high salinity tolerance was confirmed by Santagata et al. (2008), who reported 60±14% and 55±13% (mean ± s.d.) survival rates for freshwater individuals exposed to full-strength (34 PSU) seawater for 48 hours in flow-through and empty-refill treatments, respectively. These results provide evidence that current ballast water control measures may not be completely effective in preventing the introduction of this species to the Great Lakes.*

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5 √
Yes, but this species has neither been observed in ballast/fouling ships entering the Great Lakes nor in ports in direct trade with the Great Lakes.	Score x 0.1
No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0
Unknown	U

- *This species is currently widespread throughout the entire North Sea basin (lower Rhine River), Baltic Sea basin, and Black-Azov Sea basin, all of which sustain heavy amounts of Great Lakes shipping traffic (bij de Vaate et al. 2002, Grigorovich et al. 2003, Wittmann 2009).*

Vector Potential Scorecard					
Vector		**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind		**0**	x	**0**	Unlikely
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.		**0**	x	**0**	Unlikely
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)		**0**	x	**0**	Unlikely
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)		**0**	x	**0**	Unlikely
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)		**0**	x	**0**	Unlikely
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling		**80**	x 0.5	**40**	Moderate
Total Unknowns (U)	**0**	**Confidence Level**		High	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

ESTABLISHMENT POTENTIAL RESULTS

Status: Not established in North America, including the Great Lakes

***Limnomysis benedeni* has a high probability of establishment if introduced to the Great Lakes (Confidence level: Moderate).**

This species is able to survive in a relatively wide range of temperature (0-31°C) and salinity (0-14 ppt), though its minimum dissolved oxygen requirement (3.75 mg/L) is higher than that of many other freshwater invertebrates (Wittmann 2009). *Limnomysis benedeni* is able to tolerate a relatively wide range of pH (5.5-9.6), though it prefers slightly alkaline conditions (Wittmann 2009). All five Lakes would likely serve as suitable habitat under these physiological requirements; however, due to the relatively high oxygen demands, it may be restricted from establishing populations in portions of Lake Erie that undergo anoxic conditions. This species produces an overwintering generation in autumn that is able to survive in 0°C waters until the following spring (Wittmann 2009), making it a likely candidate to overwinter in the Great Lakes. It is possible that this relatively high oxygen demand may interfere with its ability to overwinter in the Great Lakes.

This species is classified as an omnivore-herbivore (Gergs et al. 2008), with a non-specific food preference (bij de Vaate et al. 2002). None of its food sources are limiting within the Great Lakes. While *L. benedeni* contributes significantly to the diets of various fish species, including perch (Bacescu 1940, Bacescu 1954, Hanselmann et al. 2011, Kelleher et al. 1999, Mordukhaĭ-Boltovskoĭ 1979b, Zhadin and Gerd 1961, Zhuravel 1956), the extent to which this predation will have an effect on preventing the establishment of potential populations in the Great Lakes is unknown.

Limnomysis benedeni has a history of outcompeting other species within its exotic range. Olenin et al. (2007) assessed the invasion effect of this species in the Curonian Lagoon as causing a moderate decline in abundance and reduction in range of native species. If it succeeds in invading fresh and brackish water Mediterranean tributaries, it has been predicted to outcompete the closely related genus *Diamysis* (Wittmann and Ariani 2000). Additionally, a loss of native macroinvertebrate species in the upper Rhine was noticed after the appearance of *L. benedeni* (Bernauer and Jansen 2006).

This species is classified as having a high fecundity (bij de Vaate et al. 2002). This, together with iteroparity and multiple generations per year give *L. benedeni* a high reproductive potential and increase its competitive ability. A single female with fertilized eggs or larvae in the brood pouch may be sufficient for founding a new population (Wittmann 2009).

Climatic conditions throughout the native range of this species are very similar to those experienced by the Great Lakes–a continental climate with dry summers (warm average temperatures > 10°C, coldest month < 0°C) (Wittmann 2009). *Limnomysis benedeni* prefers current velocities less than 0.5 m/s (Wittmann 1995), making most of the Great Lakes suitable habitat with respect to water motion. Increased salinization as a result of climate change (Rahel and Olden 2008) will likely give this species a competitive advantage over the only Great Lakes native mysid, *Mysis diluviana* (salinity tolerance 0-3 ppt) (Audzijonytė and Väinölä 2005, Ricciardi et al. 2011), as it is tolerant of salinities up to 14 ppt. Shorter ice cover duration and warmer water temperatures may also benefit this species by lengthening the suitable yearly breeding period.

Limnomysis benedeni has spread extensively throughout European waterways as a result of both intentional and unintentional introductions. Following a large number of stocking events in the Soviet Union beginning in 1947 and extending through the 1960s, this species became established in the Dnieper River (Ukraine), Lake Balaton (Hungary), and the Kaunas Reservoir (Lithuania). Genetic data suggest that this species colonized Western Europe along the southern invasion corridor from the Danube Delta, via the Main-Danube Canal, and River Rhine down to the North Sea (Audzijonytė et al. 2009). As harbors throughout Europe often mark the extent this species is distributed, shipping appears to be the main vector of dispersal (Wittmann 1995, Wittmann 2007), with construction and widening of canals contributing to its rapid spread across large distances (Wittmann 2009).

Overland transfers may also play a significant role in the spread of this species, as it has recently been found in poorly accessible water bodies in Europe (Fritz et al. 2006, Iftime and Tatole 2006, Wittmann et al. 1999, Wittmann and Ariani 2009). Proposed mechanisms of this dispersal mode include inadvertent stocking with aquatic plants or commercially valuable animals (Dumont 2006, Iftime and Tatole 2006, van der Velde et al. 2000), the aquarium trade, and overland boat transport (Wittmann and Ariani 2009). Prior to human-mediated transport, observations suggest that active swimming and passive drift along waterways were once its only means of spread (Bacescu 1940, Behning 1938). Extrapolations from its range extensions in the 1990s and 2000s suggest that eventually *L. benedeni* will be present in all major river systems of the European subcontinent that have appropriate environmental conditions (Wittmann 2009).

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
	6

- *This species is able to survive in a relatively wide range of temperature (0-31°C) and salinity (0-14 ppt), though its minimum dissolved oxygen requirement (3.75 mg/L) is higher than that of many other freshwater invertebrates (Wittmann 2009).*
- *It is able to tolerate a relatively wide range of pH (5.5-9.6), though it prefers slightly alkaline conditions (Wittmann 2009).*

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9
Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
	8

- *This species produces an overwintering generation in autumn that is able to survive in 0°C waters until the following spring (Wittmann 2009).*
- *Due to the climatic similarities between the Great Lakes and Ponto-Caspian regions (Reid and Orlova 2002) this species most likely endures similar overwintering conditions in its native range.*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
	9

- Limnomysis benedeni *is primarily microphagous, with a diet consisting of phytoplankton, epilithon, detritus, and biofilms on macrophytes, while animal prey (chironomids, etc.) play only a minor role (Dediu 1966, Gergs et al. 2008, Wittmann 2002, Wittmann and Ariani 2000).This species is classified as an omnivore-herbivore (Gergs et al. 2008), with a non-specific food preference (bij de Vaate et al. 2002).*

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	0
Unknown	U
	8

- *Olenin et al. (2007) assessed the invasion effect of this species in the Curonian Lagoon as causing a moderate decline in abundance and reduction in range of native species.*
- *If it succeeds in invading fresh and brackish water Mediterranean tributaries, it has been predicted to outcompete the closely related genus Diamysis (Wittmann and Ariani 2000). A loss of native macroinvertebrate species in the upper Rhine was noticed after the appearance of* L. benedeni *(Bernauer and Jansen 2006).*

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9

High	6
Moderate	3
Low	0
Unknown	U
	6

- *This species is classified as having a high fecundity by bij de Vaate et al. (2002) and Wittmann (2009).*

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
	9

- *High fecundity, together with iteroparity and multiple generations per year, give* L. benedeni *a high reproductive potential. A single female with fertilized eggs or larvae in the brood pouch may be sufficient for founding a new population (Wittmann 2009).*

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- *Climatic conditions throughout the native range of this species are very similar to those experienced by the Great Lakes–a continental climate with dry summers (warm average temperatures > 10°C, coldest month < 0°C) (Wittmann 2009).*

- *The Great Lakes and Ponto-Caspian region are "climatically compatible," which is one of the attributing factors to the success of Ponto-Caspian species in the Great Lakes (Reid and Orlova 2002).*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- *The temperature (0-31°C), pH (5.5-9.6), and salinity (0-14 ppt) ranges tolerated by this species (see Ecology) are all within the ranges occurring in the Great Lakes.*
- Limnomysis benedeni *prefers current velocities less than 0.5 m/s (Wittmann 1995), making most of the Great Lakes suitable habitat with respect to water motion.*
- *Abiotic factors and climatic conditions in the Ponto-Caspian region are quite similar to the Great Lakes, making the region compatible (Grigorovich et al. 2003, Reid and Orlova 2002).*
- *Great Lakes underwent similar anthropogenic eutrophication as the Ponto-Caspian region (Reid and Orlova 2002). Surface water temperature is similar between the Great Lakes and Ponto-Caspian seas (Grigorovich et al. 2003, Reid and Orlova 2002, USEPA 2008).*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0
Unknown	U
	9

- *All five Great Lakes would likely serve as suitable habitat under physiological requirements; however, due to the relatively high oxygen demands, this species may be restricted from establishing populations in portions of Lake Erie that undergo anoxic conditions.*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these	9

changes due to its wide environmental tolerances)	
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0
Unknown	U
	9

- *Increased salinization as a result of climate change (Rahel and Olden 2008) will likely give this species a competitive advantage over the only Great Lakes native mysid,* Mysis diluviana *(salinity tolerance 0-3 ppt) (Audzijonytė and Väinölä 2005, Ricciardi et al. 2011), as it is tolerant of salinities up to 14 ppt. Shorter ice cover duration and warmer water temperatures may also benefit this species by lengthening the suitable yearly breeding period.*

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
	9

- Limnomysis benedeni *is primarily microphagous, with a diet consisting of phytoplankton, epilithon, detritus, biofilms on macrophytes, and occasionally animal prey (chironomids, etc.) (Dediu 1966, Gergs et al. 2008, Wittmann 2002, Wittmann and Ariani 2000). None of these food sources are limiting within the Great Lakes.*

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare	3

in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	
Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Great Lakes and is not likely to be introduced	-80% total points (at end)
Unknown	U
	9

- *There is no critical species required by* L. benedeni.

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes)	6
Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0
Unknown	U
	0

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)

Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0
Unknown	U
	U

- *While* L. benedeni *contributes significantly to the diets of various fish species, including perch (Bacescu 1940, Bacescu 1954, Hanselmann et al. 2011, Kelleher et al. 1999, Mordukhaĭ-Boltovskoĭ 1979b, Zhadin and Gerd 1961, Zhuravel 1956), the extent to which this predation will have an effect on potential populations in the Great Lakes is unknown.*

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9
Frequent, moderate inocula	6
Frequent, small inocula OR infrequent, large inocula	3
Infrequent, small or moderate inocula	0
Unknown	U
	U

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
	9

- Limnomysis benedeni *has spread extensively throughout European waterways as a result of both intentional and unintentional introductions. Following a large number of stocking events in the Soviet Union beginning in 1947 and extending through the 1960s, this species became established in the Dnieper River (Ukraine), Lake Balaton (Hungary), and the Kaunas Reservoir (Lithuania). Genetic data suggest that this species colonized Western Europe along the southern invasion corridor from the Danube Delta, via the Main-Danube Canal, and River Rhine down to the North Sea (Audzijonytė et al. 2009). As harbors throughout Europe often mark the extent this species is distributed, shipping appears to be the main vector of dispersal (Wittmann 1995, Wittmann 2007), with construction and widening of canals contributing to its rapid spread across large distances*

(Wittmann 2009).Overland transfers may also play a significant role in the spread of this species, as it has recently been found in poorly accessible water bodies in Europe (Fritz et al. 2006, Iftime and Tatole 2006, Wittmann et al. 1999, Wittmann and Ariani 2009). Proposed mechanisms of this dispersal mode include inadvertent stocking with aquatic plants or commercially valuable animals (Dumont 2006, Iftime and Tatole 2006, van der Velde et al. 2000), the aquarium trade, and overland boat transport (Wittmann and Ariani 2009). Prior to human-mediated transport, data suggest that active swimming and passive drift along waterways were once its only means of spread (Bacescu 1940, Behning 1938).

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
	9

- *Extrapolations from its range extensions in the 1990s and 2000s suggest that eventually* L. benedeni *will be present in all major river systems of the European subcontinent that have appropriate environmental conditions (Wittmann 2009).*
- *With shipping as its main vector of dispersal, large distances can be crossed rapidly (Wittmann 2009).*

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing the establishment and spread of this species)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent the establishment and/or spread of this species	0
Unknown	U
	0

Establishment Potential Scorecard			
Points	**Probability for**	A. Total Points (pre-adjustment)	116

<table>
<tr><td></td><td>Establishment</td><td colspan="2"></td><td></td></tr>
<tr><td rowspan="2">>100</td><td rowspan="2">High</td><td colspan="2">Adjustments</td><td></td></tr>
<tr><td>B. Critical species</td><td>A*(1- 0%)</td><td>116</td></tr>
<tr><td rowspan="2">51-99</td><td rowspan="2">Moderate</td><td>C. Natural enemy</td><td>B*(1- 0%)</td><td>116</td></tr>
<tr><td>Control measures</td><td>C*(1- 0%)</td><td>116</td></tr>
<tr><td>0-50</td><td>Low</td><td colspan="2">Potential for Establishment</td><td>High</td></tr>
<tr><td># of questions answered as “unable to determine”</td><td>Confidence Level</td><td colspan="3"></td></tr>
<tr><td>0-1</td><td>High</td><td colspan="2" rowspan="2">Total # of questions unknown</td><td rowspan="2">2</td></tr>
<tr><td>2-5</td><td>Moderate</td></tr>
<tr><td>6-9</td><td>Low</td><td colspan="2" rowspan="2">Confidence Level</td><td rowspan="2">Moderate</td></tr>
<tr><td>>9</td><td>Very low</td></tr>
</table>

Section C: Potential for Impact

IMPACT POTENTIAL RESULTS

Environmental: Moderate

Socio-Economic: Low

Beneficial: Moderate

***Limnomysis benedeni* has the potential for moderate environmental impact if introduced to the Great Lakes.**

The effect of *L. benedeni* invasion in the Curonian Lagoon has been a moderate decline in abundance and reduction in range of native species (Olenin et al. 2007). Bernauer and Jansen (2006) noted a loss of native macroinvertebrate species in the upper Rhine River, Germany after the appearance of a number of invasive macroinvertebrates, including *L. benedeni*. Additionally, this species may have altered the freshwater food web in Switzerland (Gauer and Imesch 2008). Its impact on ecosystem functioning has been classified as moderate (i.e. weak modification of ecosystem performance and/or addition of a new, or reduction of existing, functional groups) (Olenin et al. 2007). It is predicted to outcompete the closely related genus *Diamysis* if it succeeds in invading fresh and brackish water Mediterranean tributaries (Wittmann and Ariani 2000).

The non-native population of *L. benedeni* in the strongly eutrophic Curonian Lagoon is reported to be a biomass dominant component of the nektobenthic community, with major significance in modifying sediment/habitat by pelletization (Olenin and Leppäkoski 1999). According to Olenin et al. (2007), this species causes alteration to the physical habitat without reducing total habitat area.

Limnomysis benedeni is a host species of burn spot disease (Austin and Alderman 1987), a bacterial shell disease causing fungal infection of the exoskeleton and gills found in a number of crustacean taxa including crayfish.

There is little or no evidence to support that *Limnomysis benedeni* has the potential for significant socio-economic impacts if introduced to the Great Lakes.

According to Austin and Alderman (1987), *L. benedeni* is vulnerable to burn spot disease, a bacterial shell disease found in shellfish, including *Oroconectes* crayfish, though the frequency and severity of possible impacts on aquaculture are unknown.

***Limnomysis benedeni* has the potential for moderate beneficial effects if introduced to the Great Lakes.**

Limnomysis benedeni is often found in the stomach of freshwater fish and has been emphasized as important food source, particularly for foraging fish (Rezsu and Specziár 2006, Zhuravel 1956). Additionally, increasing aquarist use of this species as fish fodder and as ornamental shrimp (Piepiorka and Walter 2006) is accompanied by increasing numbers of Internet offers for its sale (Wittmann and Ariani 2009) – though so far apparently only in Europe.

POTENTIAL ENVIRONMENTAL IMPACT

NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1 √
Not significantly	0
Unknown	U

- Limnomysis benedeni *is a host species of burn spot disease (Austin and Alderman 1987), a bacterial shell disease causing fungal infection of the exoskeleton and gills found in a number of crustacean taxa, including* Oroconectes *crayfish.*

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1 √

Not significantly	0
Unknown	U

- *Based on its abundance and distribution, Olenin et al. (2007) assess the invasion effect of* L. benedeni *in the Curonian Lagoon as causing a moderate decline in abundance and reduction in range of native species.*
- *This species may outcompete the closely related genus* Diamysis *if it succeeds in invading fresh and brackish water Mediterranean tributaries (Wittmann and Ariani 2000). Bernauer and Jansen (2006) noted a loss of native macroinvertebrate species in the upper Rhine River, Germany after the appearance of a number of invasive macroinvertebrates, including* L. benedeni.

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in the food web)	6
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	1 √
Not significantly	0
Unknown	U

- *Additionally, this species may have altered the freshwater food web in Switzerland (Gauer and Imesch 2008). Its impact on ecosystem functioning has been classified as moderate (i.e. weak modification of ecosystem performance and/or addition of a new, or reduction of existing, functional groups) (Olenin et al. 2007).*

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0 √
Unknown	U

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1
Not significantly	0 √
Unknown	U

E6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1 √
Not significantly	0
Unknown	U

- *The non-native population of* L. benedeni *in the strongly eutrophic Curonian Lagoon is reported to be a biomass dominant component of the nektobenthic community, with major significance in modifying sediment/habitat by pelletization (Olenin and Leppäkoski 1999). According to Olenin et al. (2007), this species causes alteration to the physical habitat without reducing total habitat area.*

Environmental Impact Total	**4**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	**Moderate**
0	0-1	Low
1	0	Low
0	≥2	Unknown
1	≥1	Unknown

POTENTIAL SOCIO-ECONOMIC IMPACT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6

Yes, but negative consequences have not been widespread, long lasting, or severe	1
Not significantly	0 √
Unknown	U

S2) Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1
Not significantly	0 √
Unknown	U

S3) Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0 √
Unknown	U

S4) Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

- *According to Austin and Alderman (1987),* L. benedeni *is vulnerable to burn spot disease, a bacterial shell disease found in shellfish, (e.g., crayfish), though the frequency and severity of possible impacts on aquaculture are unknown.*

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly	6

diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

Socio-Economic Impact Total	**0**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**Low**
1	0	
0	≥2	Unknown
1	≥1	

POTENTIAL BENEFICIAL EFFECT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular effect. An "Unknown" response is appropriate if the potential for a particular effect might be inferred but has not been explicitly reported or if there is an unresolved debate about a particular effect.

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1
Not significantly	0 √
Unknown	U

B2) Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?

Yes, it is economically important to at least one of these industries	6
Yes, but its economic contribution is small	1
Not significantly	0 √
Unknown	U

B3) Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local communities and/or tourism	6
It is sometimes employed recreationally, but adds little value to local communities or tourism	1 √
Not significantly	0
Unknown	U

- *Increasing aquarist use of this species as fish fodder and as ornamental shrimp (Piepiorka and Walter 2006) is accompanied by increasing numbers of internet offers for its sale (Wittmann and Ariani 2009).*

B4) Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR It is potentially important to medicine or research and is currently being or scheduled to be studied	1
Not significantly	0 √
Unknown	U

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1
Not significantly	0 √
Unknown	U

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1 √
Not significantly	0
Unknown	U

- L. benedeni *is often found in the stomach of freshwater fish, and is therefore often emphasized as important food source, particularly for foraging fish (Rezsu and Specziár 2006, Zhuravel 1956).*

Beneficial Effect Total	**2**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	**<u>Moderate</u>**
0	0-1	Low
1	0	
0	≥2	Unknown
1	≥1	

Scientific Name: *Paramysis (Mesomysis) intermedia* Czerniavsky, 1882

Common Name:

Synonyms:

Section A: Potential for Introduction

<u>INTRODUCTION POTENTIAL RESULTS</u>

Dispersal: Unlikely

Hitchhiking/fouling: Unlikely

Unauthorized intentional release: Unlikely

Stocking/planting/escape from recreational culture: Unlikely

Escape from commercial culture: Unlikely

Transoceanic shipping: Moderate

***Paramysis intermedia* has a moderate probability of introduction to the Great Lakes (Confidence level: High).**

Potential pathway(s) of introduction: Transoceanic Shipping (ballast water)

Paramysis intermedia does not currently occur near the Great Lakes basin. *Paramysis intermedia* is not sold, stocked, or commercially cultured. Its eggs are contained in the female's brood pouch (Borodich and Havlena 1973); thus, it is unlikely that the eggs can hitchhike or survive in ballast water. The adult forms are likely able to survive in ballast water due to their tolerance of a broad range of salinities (Ricciardi and Rasmussen 1998).

Paramysis intermedia is native to the rivers connected to the Black and Caspian seas (Birshteina et al. 1968). This species can travel downstream by moving with the current (Borodich and Havlena 1973). *Paramysis intermedia* was introduced to Lake Peipsi in the 1970s (Herkül et al. 2009). In 2008, this species was first recorded in the Gulf of Riga and the Gulf of Finland of the Baltic Sea. *Paramysis intermedia* occurs in ports that have direct trade connections with the Great Lakes (NBIC 2009). There are nonindigenous occurrences of *Paramysis intermedia* in waters that contain species that were introduced via ballast water (Ricciardi and Rasmussen 1998).

Paramysis intermedia may be introduced to the Great Lakes via ships declaring "No Ballast on Board" (NOBOB), which are exempt from ballast water exchange. The majority of ships entering the Great Lakes are NOBOB vessels and 43% of these ships contain residual water with less than 10‰ salinity (Johengen et al. 2005). In the study, the temperature of the residual water from the vessels sampled ranged from -0.7 to 23.9°C; thus *Paramysis intermedia* is likely to survive the salinity and temperature of the NOBOB ballast water.

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100
No, this species does not occur near waters connected to the Great Lakes basin and/or is not mobile or able to be transported by wind or water.	0 √
Unknown	U

- *The species* Paramysis intermedia *does not occur in waters near the Great Lakes basin.* P. intermedia *is native to rivers connected to the Caspian Sea, Azov Sea and Black Sea.(Birshteina et. Al 1968)*
- Paramysis intermedia *has been known to inhabit the Ponto-Caspian region and has also been introduced to Lake Peispi (Herkül et.al 2009).*
- *Observations of Ponto-Caspian species outside of their native range in European continental waters make clear that there are at least three main vectors for their spread west-ward. I) Construction of canals connecting river basins, II) water management in some canals and III) transportation attached to a vessel's hull in ballast water (bij de Vaate et al. 2002).*

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0 √
Unknown	U

- *Mysid crustaceans in general have poor dispersal due to their morphology. They carry their eggs and developing young in a brood pouch, cannot withstand desiccation and typically cannot actively disperse upstream; their continental distributions have therefore been largely defined by direct (lentic) waterway connections (Audzijonytė et al. 2006, Bănărescu 1991).*
- *The species is not proximal to the Great Lakes basin. Paramysis species can be found in the Ponto-Caspian basin, Mediterranean Sea and Black and Azov Sea.*

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a) Is this species sold at aquarium/pet/garden stores ("brick & mortar" or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100
No, this species this species is rarely/never sold.	0 √
Unknown	U

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0 √
Unknown	U

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km	Score x 0.75

of the Great Lakes basin.	
This activity is likely to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces), this activity may occur within 20 km of the basin because of the species' popularity/value.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100
No, this species is not commercially cultured in or transported through the Great Lakes region.	0 √
Unknown	U

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80 √
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40

No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0
Unknown	U

- *With the exception of some microbes, little is known regarding survival of freshwater organism in saline water. The survival rate of freshwater organisms immersed in saline ballast water is certainly much lower than that in fresh water (MacIssac et al. 2002).*
- *Ponto-Caspian mysids exhibit a variety of salinity tolerances, involving both strictly stenohaline (<3%) and relatively euryhaline (0-12%) taxa (Daneliya 2003, Komarova 1991).*
- *According to (Daneliya 2003), euryhalinity should have been an important ecophysiological property controlling the dispersal of species.*
- *Ricciardi and Rasmussen (1998) identified* P. intermedia *as one of the Ponto-Caspian euryhaline macroinvertebrate species with invasion history. They also reported that* P. intermedia *along with other species were transported in ballast water.*
- *This species occupies estuaries and lagoons (Audzijonytė et al. 2006) and estuaries are naturally highly stressed environments. They are inhabited by stress-tolerant biota (Dauvin et al. 2007) that has to cope with high natural loads of organic matter and decreased salinity.*
- *(Bonsdorff and Pearson 1999) report that in Northeastern Baltic Sea, harsh environmental conditions result in a low number of benthic species. These species can be considered very tolerant to various disturbances including anthropogenic stresses .*

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5√
Yes, but this species has neither been observed in ballast/fouling ships entering the Great Lakes nor in ports in direct trade with the Great Lakes.	Score x 0.1
No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0
Unknown	U

- *Present in: Azov sea, Baltic sea, Black Sea, Caspian Sea, United Kingdom Exclusive Economic Zone*

Vector Potential Scorecard					
Vector		**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind		**0**	x	**0**	Unlikely
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.		**0**	x	**0**	Unlikely
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)		**0**	x	**0**	Unlikely
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)		**0**	x	**0**	Unlikely
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)		**0**	x	**0**	Unlikely
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling		**80**	x 0.5	**40**	Moderate
Total Unknowns (U)	**0**	**Confidence Level**		High	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

ESTABLISHMENT POTENTIAL RESULTS

Status: **Not established in North America, including the Great Lakes**

***Paramysis intermedia* has a moderate probability of establishment if introduced to the Great Lakes (Confidence level: High).**

The native and introduced ranges of *Paramysis intermedia* have similar climate and abiotic conditions to that of the Great Lakes (Grigorovich et al. 2003, Reid and Orlova 2002, USEPA 2008). This species is likely capable of overwintering in the Great Lakes; it occurs in reservoirs elsewhere that have ice cover in the winter (Borodich and Havlena 1973). *Paramysis intermedia* prefers shallow, sandy habitats; thus this species is likely to find a suitable habitat in the Great Lakes. This species may benefit from increased salinization attributed to climate change because it can better tolerate higher salinities compared to species native to the Great Lakes. *Paramysis intermedia* has the potential to invade North American lakes that currently lack other mysid shrimp (Ricciardi and Rasmussen 1998).

Paramysis intermedia has a non-specific, omnivorous diet; it will probably find an appropriate food source in the Great Lakes. *Paramysis intermedia* can produce up to 3 broods per year (Borodich and Havlena 1973). *Paramysis intermedia* produces an average of 7-30 embryos, which is slightly less than the number of embryos produced by *Paramysis ullskyi*.

Paramysis intermedia was intentionally introduced to Lake Peipsi, but did not establish a permanent population (Herkül et al. 2009). This species was deliberately introduced to the Volga River and successfully established a population in its lower reaches and predominates the mysid community there (Borodich and Havlena 1973). In the 1960s, *Paramysis intermedia* was introduced from the Don River to the Aral Sea and became numerous in 1961 (Aladin et al. 2004).

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
	7

- *Ponto-Caspian mysids exhibit a variety of salinity tolerances, involving both strictly stenohaline (<3%) and relatively euryhaline (0-12%) taxa (Daneliya 2003, Komarova 1991).*
- *This species occupies estuaries and lagoons (Audzijonytė et al. 2006) and estuaries are naturally highly stressed environments. They are inhabited by stress-tolerant biota (Dauvin et al. 2007) that has to cope with high natural loads of organic matter and decreased salinity.*

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9

Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
	8

- Paramysis intermedia *has been found in the rivers of the Ponto-Caspian, as well as the Baltic Sea (Herkül et al. 2009, Kotta and Möller 2009).*
- *This species inhabits cold freshwaters, though reproduction ceased below 10°C (Wooldridge 1986).*
- Paramysis intermedia *exist in reservoirs that have ice cover over winter, reproduce at 6-7°C (Borodich and Havlena 1973).*
- *Due to the climatic similarities between the Great Lakes and Ponto-Caspian regions (Reid and Orlova 2002) this species most likely endures similar overwintering conditions in its native range.*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
	7

- *Ponto-Caspian macroinvertebrates have a non-specific food preference which is one of the biological factors that contributes to the invasion of regions beyond their native range (bij de Vaate et al. 2002)*
- *Mysidopsis species are omnivorous and cannibalistic, feeding on diatoms and small crustaceans such as copepods (Mauchline 1980). However, this particular species of mysid has a non-specific food source and therefore should not have trouble finding an appropriate food source.*

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	0

Unknown	U
	2

- *When studied, this species is found in low relative abundance (Herkül et al. 2009, Kotta and Möller 2009); however, has been found co-occuring with two other Ponto-Caspian invaders (C. cuvispinum and P. robustoides) (Herkül et al. 2009)*
- Paramysis intermedia *has reached 200-500 individuals/m^2 in Volga river (Borodich and Havlena 1973)*

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
	2

- *Number of embryos of this species ranges from a mean of 7-30, based on female body size (3 generations). This is slightly less than* P. ullskyi*, which has mean range from 17-55 embryos (2 generations) (Borodich and Havlena 1973).*

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
	3

- Paramysis intermedia *is commonly called possum shrimp because the females carry their developing young in a bulging pouch or marsupium formed by at the base of their legs. The young mysids are not released until they are well-developed juveniles. Females produce young continuously, refilling their pouch with eggs as soon as their latest brood is released. The juvenile Mysids will reach their adult size of 1 inch (1.25 cm) in about 3 weeks, creating a new generation every 30 days (Marini and Moe 2003).*

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- Paramysis intermedia *has been found in the rivers of the Ponto-Caspian, as well as the Baltic Sea (Herkül et al. 2009, Kotta and Möller 2009). The Great Lakes and Ponto-Caspian region are climatically compatible, which is one of the attributing factors to the success of Ponto-Caspian species in the Great Lakes (Reid and Orlova 2002).*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- Paramysis intermedia *has been found in the rivers of the Ponto-Caspian, as well as the Baltic Sea (Herkül et al. 2009, Kotta and Möller 2009).*
- *Abiotic factors and climatic conditions of the native and introduced ranges of* P. intermedia *are quite similar to the Great Lakes, making the region compatible (Grigorovich et al. 2003, Reid and Orlova 2002).*
- *Great Lakes underwent similar anthropogenic eutrophication as the Ponto-Caspian region (Reid and Orlova 2002). Surface water temperature is similar between the Great Lakes and Ponto-Caspian seas (Grigorovich et al. 2003, Reid and Orlova 2002, USEPA 2008).*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3

Scarce (Suitable habitats are rarely found)	0
Unknown	U
	7

- *This species has been found at depths of 1-2.1m, with sandy bottom (Herkül et al. 2009)*
- Paramysis intermedia *prefers sandy shallow-water habitat (Borodich and Havlena 1973)*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0
Unknown	U
	6

- *This mysid can tolerate higher salinity waters, especially relative to native Great Lakes species.*

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
	9

- *Mysidopsis species are omnivorous and cannibalistic, feeding on diatoms and small crustaceans such as copepods (Mauchline 1980). However, this particular species of mysid has a non-specific food source and therefore should not have trouble finding an appropriate food source.*

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Great Lakes and is not likely to be introduced	-80% total points (at end)
Unknown	U
	9

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes)	6
Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0
Unknown	U
	0

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in	-80% total

introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0
Unknown	U
	0

- *While juvenile fish may feed on this mysid, it will likely not prevent its establishment.*

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9
Frequent, moderate inocula	6
Frequent, small inocula OR infrequent, large inocula	3
Infrequent, small or moderate inocula	0
Unknown	U
	U

- *With no resting stage, ballast introductions of this species would be rare.*

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
	3

- *In 2008* P. intermedia *was found for the first time in the Baltic Sea. There were two separate records in 2008, one from the Gulf of Riga and the other from the eastern Gulf of Finland. Although* P. intermedia *did not form a permanent population in Lake Peipsi after its deliberate introduction in the 1970s, the species might have survived in the Narva River and is currently invading the coastal sea. The invasion corridor of the Gulf of Riga population remains unknown (Herkül et al. 2009).*

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
	2

- *Although* P. intermedia *did not form a permanent population in Lake Peipsi after its deliberate introduction in the 1970s, the species might have survived in the Narva River and is currently invading the coastal sea.*

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing the establishment and spread of this species)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent the establishment and/or spread of this species	0
Unknown	U
	0

Establishment Potential Scorecard				
Points	**Probability for Establishment**	A. Total Points (pre-adjustment)		81
>100	High	**Adjustments**		
		B. Critical species	A*(1- 0%)	81

51-99	Moderate	C. Natural enemy	B*(1- 0%)	81
		Control measures	C*(1- 0%)	81
0-50	Low	**Potential for Establishment**		Moderate
# of questions answered as "unable to determine"	**Confidence Level**			
0-1	High	Total # of questions unknown		1
2-5	Moderate			
6-9	Low	Confidence Level		High
>9	Very low			

Section C: Potential for Impact

IMPACT POTENTIAL RESULTS

Environmental: Unknown

Socio-Economic: Low

Beneficial: Low

Current research on the potential for environmental impacts to result from *Paramysis intermedia* if introduced to the Great Lakes is inadequate to support proper assessment.

If introduced to the Great Lakes, *Paramysis intermedia* may reduce zooplankton biomass through feeding, and consequently impact planktivorous fish populations (Ricciardi and Rasmussen 1998, Spencer et al. 1991); however, studies have not been conducted to determine if these effects are significant where *Paramysis intermedia* has been introduced. Studies suggest that due to biomagnification of contaminants from mysids to fish, levels of PCB and mercury in pelagic fish are higher in North American lakes that contain mysids compared to those that lack mysids (Cabana et al. 1994, Rasmussen et al. 1990); however, the aforementioned studies do not specifically investigate the impacts of *Paramysis intermedia* on biomagnification of contaminants.

There is little or no evidence to support that *Paramysis intermedia* has the potential for significant socio-economic impact if introduced to the Great Lakes.

It has not been reported that *Paramysis intermedia* poses a threat to human health or water quality. There is no evidence that this species negatively impacts infrastructure, economic sectors, recreational activities and associated tourism, or the aesthetic appeal of the areas it inhabits.

There is little or no evidence to support that *Paramysis intermedia* has the potential for significant beneficial impacts if introduced to the Great Lakes.

It is unknown if the introduction of *Paramysis intermedia* to the Great Lakes would increase fish productivity. *Paramysis intermedia* was intentionally introduced to fisheries in Europe to improve productivity. However, it can potentially compete with fish for zooplankton and harm fish populations (Ricciardi and Rasmussen 1998, Spencer et al. 1991). It has not been indicated that *Paramysis intermedia* can be used for the control of other organisms or improving water quality. There is no evidence to suggest that this species is medically valuable. It does not have significant positive ecological impacts.

POTENTIAL ENVIRONMENTAL IMPACT

NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1
Not significantly	0
Unknown	U √

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1
Not significantly	0
Unknown	U √

- *When studied this species has been found in low relative abundance (Herkül et al. 2009, Kotta and Möller 2009); however, has been found co-occuring with two other Ponto-Caspian invaders (*C. cuvispinum *and* P. robustoides*) (Herkül et al. 2009)*
- Paramysis intermedia *has reached 200-500 individuals/m^2 in Volga river (Borodich and Havlena 1973)*

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in the food web)	6
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the	1

effects of which have not been widespread or severe	
Not significantly	0
Unknown	U √

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0
Unknown	U √

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1
Not significantly	0
Unknown	U √

E6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1
Not significantly	0
Unknown	U √

Environmental Impact Total	**0**
Total Unknowns (U)	**6**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	Low
1	0	
0	≥2	**Unknown**
1	≥1	

POTENTIAL SOCIO-ECONOMIC IMPACT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1
Not significantly	0 √
Unknown	U

S2) Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1
Not significantly	0 √
Unknown	U

S3) Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0 √
Unknown	U

S4) Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

Socio-Economic Impact Total	**0**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**<u>Low</u>**
1	0	
0	≥2	Unknown
1	≥1	

POTENTIAL BENEFICIAL EFFECT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular effect. An "Unknown" response is appropriate if the potential for a particular effect might be inferred but has not been explicitly reported or if there is an unresolved debate about a particular effect.

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1
Not significantly	0 √
Unknown	U

B2) Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?

Yes, it is economically important to at least one of these industries	6
Yes, but its economic contribution is small	1
Not significantly	0 √
Unknown	U

B3) Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local communities and/or tourism	6
It is sometimes employed recreationally, but adds little value to local communities or tourism	1
Not significantly	0 √
Unknown	U

B4) Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR It is potentially important to medicine or research and is currently being or scheduled to be studied	1
Not significantly	0 √
Unknown	U

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1
Not significantly	0 √
Unknown	U

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1
Not significantly	0 √
Unknown	U

Beneficial Effect Total	**0**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**Low**
1	0	
0	≥2	Unknown
1	≥1	

Scientific Name: *Paramysis (Metamysis) ullskyi*
Czerniavsky, 1882

Common Name: Mysid Shrimp

Synonyms:

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: Unlikely

Hitchhiking/fouling: Unlikely

Unauthorized intentional release: Unlikely

Stocking/planting/escape from recreational culture: Unlikely

Escape from commercial culture: Unlikely

Transoceanic shipping: Moderate

***Paramysis ullskyi* has a moderate probability of introduction to the Great Lakes (Confidence level: High).**

Potential pathway(s) of introduction: Transoceanic Shipping (ballast water)

Paramysis intermedia does not currently occur near the Great Lakes Basin. *Paramysis intermedia* is not sold, stocked, or commercially cultured. Its eggs are contained in the female's brood pouch (Borodich and Havlena 1973); thus, it is unlikely that the eggs can hitchhike or survive in ballast water. The adult forms are likely able to survive in ballast water due to their tolerance of a broad range of salinities (Ricciardi and Rasmussen 1998).

Paramysis intermedia may be introduced to the Great Lakes via ships declaring "No Ballast on Board" (NOBOB), which are exempt from ballast water exchange. The majority of ships entering the Great Lakes are NOBOB vessels and 43% of these ships contain residual water with less than 10‰ salinity (Johengen et al. 2005). In the study, the temperature of the residual water from the vessels sampled ranged from -0.7 to 23.9°C; thus *Paramysis intermedia* is likely to survive the salinity and temperature of the NOBOB ballast water.

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100
No, this species does not occur near waters connected to the Great Lakes basin and/or is not mobile or able to be transported by wind or water.	0 √
Unknown	U

- *This species occurs in European part of Russia, Baltic Sea, Caspian Sea, North Atlantic near Russia.*
- *The species is indigenous to waters surrounding the western part of Russia, as well as the Baltic, Caspian, and north Atlantic near Russia.*

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0 √
Unknown	U

- Paramysis ullskyi *is indigenous to the European part of Russia in the Ponto-Caspian basin.*

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a) Is this species sold at aquarium/pet/garden stores ("brick & mortar" or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100
No, this species this species is rarely/never sold.	0 √
Unknown	U

- *While the specific species is not stated, similar mysid shrimp indigenous to the same area has been used as fish food for fauna enrichment in the Soviet Union back in the 1970s. However, it is unknown whether this is still in practice today, or if particular mysids are used for fish farms in the United States.*
- *No evidence was shown that this particular species has arrived to the Great Lakes nor is there any recent evidence of this species being used currently in either Russia or the United States.*

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0 √
Unknown	U

- *It is only known to be used for fish and fauna enrichment around the Ponto-Caspian area around Russia.*

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is likely to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces), this activity may occur within 20 km of the basin because of the species' popularity/value.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100
No, this species is not commercially cultured in or transported through the Great Lakes region.	0 √
Unknown	U

- *While there has been history of transport, similar species have been transported only throughout Russia, and not to the Great Lakes.*

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80 √
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40
No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0
Unknown	U

- *While* Paramysis *has a broad range in salinity tolerance, Ovcarenko (2006) has shown that there is high mortality when the salinity change is really sudden, such as when changing ballast water. Mortality occurs when they approach 15 PSU.*

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5 √
Yes, but this species has neither been observed in ballast/fouling ships entering the Great Lakes nor in ports in direct trade with the Great Lakes.	Score x 0.1
No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0
Unknown	U

- *The species is indigenous to the European part of Russia in the Ponto-Caspian basin.*
- *This species occurs in European part of Russia, Baltic Sea, Caspian Sea, North Atlantic near Russia.*
- *The species is indigenous to waters surrounding the western part of Russia, as well as the Baltic, Caspian, and north Atlantic near Russia.*

Vector Potential Scorecard				
Vector	**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind	**0**	x	**0**	Unlikely
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.	**0**	x	**0**	Unlikely
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)	**0**	x	**0**	Unlikely
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)	**0**	x	**0**	Unlikely
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)	**0**	x	**0**	Unlikely
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling	**80**	x 0.5	**40**	Moderate
Total Unknowns (U)	**0**	**Confidence Level**	High	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High

40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

ESTABLISHMENT POTENTIAL RESULTS

Status: **Not established in North America, including the Great Lakes**

***Paramysis ullskyi* has a moderate probability of establishment if introduced to the Great Lakes (Confidence level: moderate)**

The native and introduced ranges of *Paramysis intermedia* have similar climate and abiotic conditions to that of the Great Lakes (Grigorovich et al. 2003, Reid and Orlova 2002, USEPA 2008). This species is likely capable of overwintering in the Great Lakes; it occurs in reservoirs elsewhere that have ice cover in the winter (Borodich and Havlena 1973). *Paramysis intermedia* prefers shallow, sandy habitats; thus this species is likely to find a suitable habitat in the Great Lakes. This species may benefit from increased salinization attributed to climate change because it can better tolerate higher salinities compared to species native to the Great Lakes. *Paramysis intermedia* has the potential to invade North American lakes that currently lack other mysid shrimp (Ricciardi and Rasmussen 1998).

Paramysis intermedia has a non-specific, omnivorous diet; it will probably find an appropriate food source in the Great Lakes. *Paramysis intermedia* can produce up to 3 broods per year (Borodich and Havlena 1973). *Paramysis intermedia* produces an average of 7-30 embryos, which is slightly less than the number of embryos produced by *Paramysis ullskyi*.

Paramysis intermedia was intentionally introduced to Lake Peipsi, but did not establish a permanent population (Herkül et al. 2009). This species was deliberately introduced to the Volga River and successfully established a population in its lower reaches and predominates the mysid community there (Borodich and Havlena 1973). In the 1960s, *Paramysis intermedia* was introduced from the Don River to the Aral Sea and became numerous in 1961 (Aladin et al. 2004).

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive	6

in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
	7

- *The Ponto-Caspian region, where* P. ullskyi *originates, is quite similar to the Great Lakes. The spatial temperature mean is 13.7 degrees with a range of 12.1 to 16.1.*
- Paramysis ullskyi *cannot tolerate a sudden salinity change to 18 PSU levels of salinities, and its natural salinity environment was 3 psu. (Ovcarenko 2006).*

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9
Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
	8

- *Given their origins around northern Russia, mysid shrimp can survive long periods of time within colder and deeper waters.*
- Parmysis ullskyi *exist in reservoirs that have ice cover over winter, reproduce at 6-7˚C (Borodich and Havlena 1973).*
- *Due to the climatic similarities between the Great Lakes and Ponto-Caspian regions (Reid and Orlova 2002) this species most likely endures similar overwintering conditions in its native range.*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
	7

- Paramysis ullskyi *mainly consumes the detritus of surface ground laters (Borodich and Havlena 1973).*

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	0
Unknown	U
	3

- *Mysids can cause a lowering of zooplankton abundance (Ketelaars et al. 1999).*

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
	5

- *Nothing specific has been shown to differentiate the reproductive ability from other similar species within the same taxa.*
- *The number of embryos ranges from a mean of 17-55, based on female body size (2 generations). This is slightly more than* P. intermedia*, which has mean range from 7-30 embryos (3 generations) (Borodich and Havlena 1973).*

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid	0

establishment in new environments)	
Unknown	U
	3

- *This species is a brooder.*
- Paramysis ullskyi *abilities and tolerances make it likely, but only literature found on invasions of other European lakes have been found.*

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	7

- *The Great Lakes are known to change seasons, having an average temperature of less than 5˚C on the surface in the winter months, then 5 – 15 degrees with the onset of spring, and up to 25 degrees in the summer (data from the NOAA Coastwatch Great Lakes website, specifically to Lake Ontario.*
- *The Ponto-Caspian region, where* P. ullskyi *originates, is actually quite similar. The spatial temperature mean is 13.7 degrees with a range of 12.1 to 16.1. This is warmer, but climate change would cause the Great Lakes to be more similar (USEPA 2008).*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- Paramysis ullskyi *is known to live in 0-4% salinity (Audzijonytė et al. 2006), and their native lake salinities have a wide range, with the Black Sea reaching salinities of 22 ppt, the Azov up to 12 ppt, and the Caspian reaching 13 ppt. The Great Lakes salinities tend to be close to 0.*
- *The Great Lakes and Ponto-Caspian region are climatically compatible, which is one of the attributing factors to the success of Ponto-Caspian species in the Great Lakes (Reid and Orlova 2002).*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0
Unknown	U
	8

- Paramysis intermedia *prefers sandy shallow-water habitat (Borodich and Havlena 1973).*
- *Abiotic factors and climatic conditions in the Ponto-Caspian region are quite similar to the Great Lakes, making the region compatible (Grigorovich et al. 2003, Reid and Orlova 2002).*
- *Great Lakes underwent similar anthropogenic eutrophication as the Ponto-Caspian region (Reid and Orlova 2002). Surface water temperature is similar between the Great Lakes and Ponto-Caspian seas (Grigorovich et al. 2003, Reid and Orlova 2002, USEPA 2008).*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0
Unknown	U
	7

- *The Ponto-Caspian region, where* P. ullskyi *originates, is actually quite similar to the Great Lakes.. The spatial temperature mean is 13.7 degrees with a range of 12.1 to 16.1. This is warmer, but climate change would cause the Great Lakes to be more similar (USEPA 2008).*
- *Due to their wider temperature tolerances,* Paramysis ullskyi *can be very adaptable to warmer temperatures and shallower waters. Even though the Great Lakes may be slightly colder in the winters than what the species may be used to, climate change would adjust that factor in the future (USEPA 2008).*

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9

Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
	9

- *Much of the sustenance of* Paramysis ullskyi *can be found both in their native waters and in the Great Lakes. They survive on algae and zooplankton (Ketelaars et al. 1999).*

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Great Lakes and is not likely to be introduced	-80% total points (at end)
Unknown	U
	9

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes)	6

Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0
Unknown	U
	0

- *There was no indication of this species that would facilitate their establishment.*

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0
Unknown	U
	0

- *Larger fish have always been the main predator of mysid shrimp, though a specific one is not mentioned. This hasn't really controlled the native mysid shrimp in the Great Lakes region.*

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9
Frequent, moderate inocula	6
Frequent, small inocula OR infrequent, large inocula	3
Infrequent, small or moderate inocula	0
Unknown	U
	U

- *There were multiple reports of invasions in Europe outside the Ponto-Caspian but it did not mention anything on frequency (Ketelaars 1997).*

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
	8

- Paramysis ullskyi *was spread via ballast water to other Baltic lakes throughout Europe. This was shown through actual physical observation and mitochondrial DNA tracking of migrating species. (Audzijonytė 2008, bij de Vaate et al. 2002)*

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
	U

- *In the 1950s*, H. anomala*, a similar species with nearly the same origins in the Ponto-Caspian area, were intentionally introduced in fisheries in the Dnieper River, and in the Dubossart reservoir in Moldovia. Throughout the 70s and onward, mysids distributed through Europe vie rivers and tributaries (bij de Vaate et al. 2002)*

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing the establishment and spread of this species)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used	-50% total points (at

to control its establishment and spread)	end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent the establishment and/or spread of this species	0
Unknown	U
	0

Establishment Potential Scorecard				
Points	**Probability for Establishment**	A. Total Points (pre-adjustment)		89
>100	High	**Adjustments**		
		B. Critical species	A*(1- 0%)	89
51-99	Moderate	C. Natural enemy	B*(1- 0%)	89
		Control measures	C*(1- 0%)	89
0-50	Low	**Potential for Establishment**		Moderate
# of questions answered as "unable to determine"	**Confidence Level**			
0-1	High	Total # of questions unknown		2
2-5	Moderate			
6-9	Low	Confidence Level		Moderate
>9	Very low			

Section C: Potential for Impact

IMPACT POTENTIAL RESULTS

Environmental: High

Socio-Economic: Low

Beneficial: Low

Current research on the potential for environmental impacts to result from *Paramysis intermedia* if introduced to the Great Lakes is inadequate to support proper assessment.

If introduced to the Great Lakes, *Paramysis intermedia* may reduce zooplankton biomass through feeding, and consequently impact planktivorous fish populations (Ricciardi and Rasmussen 1998, Spencer et al. 1991); however, studies have not been conducted to determine if these effects are significant where *Paramysis intermedia* has been introduced. Studies suggest that due to biomagnification of contaminants from mysids to fish, levels of PCB and mercury in pelagic fish are higher in North American lakes that contain mysids compared to those that lack mysids (Cabana et al. 1994, Rasmussen et al. 1990); however, the aforementioned studies do not specifically investigate the impacts of *Paramysis intermedia* on biomagnification of contaminants.

There is little or no evidence to support that *Paramysis intermedia* has the potential for significant socio-economic impact if introduced to the Great Lakes.

It has not been reported that *Paramysis intermedia* poses a threat to human health or water quality. There is no evidence that this species negatively impacts infrastructure, economic sectors, recreational activities and associated tourism, or the aesthetic appeal of the areas it inhabits.

There is little or no evidence to support that *Paramysis intermedia* has the potential for significant beneficial impacts if introduced to the Great Lakes.

It is unknown if the introduction of *Paramysis intermedia* to the Great Lakes would increase fish productivity. *Paramysis intermedia* was intentionally introduced to fisheries in Europe to improve productivity. However, it can potentially compete with fish for zooplankton and harm fish populations (Ricciardi and Rasmussen 1998, Spencer et al. 1991). It has not been indicated that *Paramysis intermedia* can be used for the control of other organisms or improving water quality. There is no evidence to suggest that this species is medically valuable. It does not have significant positive ecological impacts.

POTENTIAL ENVIRONMENTAL IMPACT

NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1
Not significantly	0
Unknown	U √

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6 √
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival,	1

fecundity) or decline of at least one native population	
Not significantly	0
Unknown	U

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in the food web)	6
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	1 √
Not significantly	0
Unknown	U

- *Ketelaars (1997) mentions an almost absent population of in zooplankton and phytoplankton biomass as a result of invasion, in a span of almost a decade. While this is referencing* Hemimysis anomola*, this reference also indicates that* Paramysis *is part of the most frequent Ponto-Caspian invaders they are researching, and it is known that* H. anomala *and* Paramysis *are part of the same taxonomic subfamily, only differing in genus (Mees 2015).*
- *Mysid shrimp tend to be the preferred choice of prey for many fish species, but this does not impact their invasiveness significantly.*

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0 √
Unknown	U

- *There was no mention of any alteration to species.*

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1
Not significantly	0
Unknown	U √

- *It can be speculated that it can, considering that colonies of paramysis and feed on vast quantities of algae as well as reduce populations of zooplankton and phytoplankton (Porter et al. 2008). Theoretically, it can increase clarity and alter certain chemical content.*

E6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1
Not significantly	0
Unknown	U √

Environmental Impact Total	**7**
Total Unknowns (U)	**3**

Scoring		
Score	# U	**Impact**
>5	Any	**High**
2-5	Any	Moderate
0	0-1	Low
1	0	
0	≥2	Unknown
1	≥1	

POTENTIAL SOCIO-ECONOMIC IMPACT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1

Not significantly	0 √
Unknown	U

- *There was no mention other than possible ecological effects.*

S2) Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1
Not significantly	0 √
Unknown	U

S3) Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0 √
Unknown	U

- *It has only been reported to have decreased alga levels as well as overall diversity of the food web.*

S4) Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

- *Not negatively, but in fact related paramysis species have been a frequent choice of commercial fisheries since they are prime food sources for new fauna.*

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly	6

diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

Socio-Economic Impact Total	**0**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**Low**
1	0	
0	≥2	Unknown
1	≥1	

POTENTIAL BENEFICIAL EFFECT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular effect. An "Unknown" response is appropriate if the potential for a particular effect might be inferred but has not been explicitly reported or if there is an unresolved debate about a particular effect.

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1
Not significantly	0 √
Unknown	U

B2) Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?

Yes, it is economically important to at least one of these industries	6
Yes, but its economic contribution is small	1 √
Not significantly	0
Unknown	U

- *Mysid shrimp has been used extensively to feed fisheries, mainly because they are relatively easy to culture because to their wide habitat tolerances (Marini and Moe 2003).*

B3) Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local communities and/or tourism	6
It is sometimes employed recreationally, but adds little value to local communities or tourism	1
Not significantly	0 √
Unknown	U

B4) Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR It is potentially important to medicine or research and is currently being or scheduled to be studied	1
Not significantly	0 √
Unknown	U

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1
Not significantly	0 √
Unknown	U

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1
Not significantly	0 √
Unknown	U

Beneficial Effect Total	**1**
Total Unknowns (U)	**0**

<table>
<tr><th colspan="3">Scoring</th></tr>
<tr><th>Score</th><th># U</th><th>Impact</th></tr>
<tr><td>>5</td><td>Any</td><td>High</td></tr>
<tr><td>2-5</td><td>Any</td><td>Moderate</td></tr>
<tr><td>0</td><td>0-1</td><td rowspan="2"><u>Low</u></td></tr>
<tr><td>1</td><td>0</td></tr>
<tr><td>0</td><td>≥2</td><td rowspan="2">Unknown</td></tr>
<tr><td>1</td><td>≥1</td></tr>
</table>

Scientific Name: *Paramysis (Serrapalpisis) lacustris*
Czerniavsky, 1882

Common Name: Opossum Shrimp

Synonyms:

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: Unlikely

Hitchhiking/fouling: Unlikely

Unauthorized intentional release: Unlikely

Stocking/planting/escape from recreational culture: Unlikely

Escape from commercial culture: Unlikely

Transoceanic shipping: Moderate

***Paramysis lacustris* has a moderate probability of introduction to the Great Lakes (Confidence level: High).**

Potential pathway(s) of introduction: Transoceanic Shipping

Paramysis lacustris has been observed in ballast waters of ships in the North Sea (Gollasch 2002) and is considered to have the potential for introduction to the Great Lakes via European ballast water transport (Ricciardi and Rasmussen 1998). In a recent study, *P. lacustris* showed a mortality rate of 60% after 24 hours of exposure to a salinity of 19 PSU, and a mortality rate of 100% with exposure to 23 PSU (Ovcarenko et al. 2006). Considering this relatively high short-term salinity tolerance, ballast water regulations requiring salinities of at least 30 PSU are believed to be an appropriate means of control (Ovcarenko et al. 2006). More recently, under current mandatory ballast water regulations (flushing with at least 30 ppt), the risk of entry for this particular species has been modeled as low due to these physiological salinity constraints (Grigorovich et al. 2003).

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100
No, this species does not occur near waters connected to the Great Lakes basin and/or is not mobile or able to be transported by wind or water.	0 √

Unknown	U

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0 √
Unknown	U

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a) Is this species sold at aquarium/pet/garden stores ("brick & mortar" or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100
No, this species this species is rarely/never sold.	0 √
Unknown	U

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0 √
Unknown	U

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is <u>likely</u> to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces), this activity <u>may</u> occur within 20 km of the basin because of the species' popularity/value.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100
No, this species is not commercially cultured in or transported through the Great Lakes region.	0 √
Unknown	U

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80 √
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40
No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0
Unknown	U

- Paramysis lacustris *is considered to have the potential for introduction to the Great Lakes via European ballast water transport (Ricciardi and Rasmussen 1998).*
- *This species showed a mortality rate of 60% after 24 hours of exposure to salinity of 19 PSU, and a mortality rate of 100% with exposure to 23 PSU (Ovcarenko et al. 2006). Considering this relatively high short-term salinity tolerance, ballast water regulations requiring salinity flushing with at least 30 PSU are believed to be an appropriate means of control (Ovcarenko et al. 2006).*
- *Under mandatory ballast water regulations, the risk of entry for this particular species has been modeled as low due to physiological salinity constraints (Grigorovich et al. 2003).*

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5 √
Yes, but this species has neither been observed in ballast/fouling ships entering the Great Lakes nor in ports in direct trade with the Great Lakes.	Score x 0.1
No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0

Unknown	U

- Paramysis lacustris *has been observed in ballast waters of the North Sea, a region where Great Lakes shipping traffic originates (Gollasch 2002). There are no current records of this species being observed in ships entering the Great Lakes.*

Vector Potential Scorecard				
Vector	**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind	**0**	x	**0**	Unlikely
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.	**0**	x	**0**	Unlikely
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)	**0**	x	**0**	Unlikely
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)	**0**	x	**0**	Unlikely
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)	**0**	x	**0**	Unlikely
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling	**80**	x 0.5	**40**	Moderate
Total Unknowns (U) **0**		**Confidence Level**	High	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

ESTABLISHMENT POTENTIAL RESULTS

Status: Not established in North America, including the Great Lakes

***Paramysis lacustris* has a moderate probability of establishment if introduced to the Great Lakes (Confidence level: Moderate).**

Paramysis lacustris is recognized as a stenohaline species, typically occurring in salinities of 0-3 PSU (Daneliya 2002, Komarova 1991); however, it has been able to survive short-term salinity exposures of up to 24 PSU (Santagata 2008). A particular trait of *P. lacustris* that causes increased concern over invasion is its adaptation to water temperatures up to 20°C, while the coldwater mysids already present in the Great Lakes only tolerate temperatures of up to about 10°C (Bondarenko and Yablonskaya 1979). *Paramysis lacustris* have been known to survive in situ in temperatures up to 28°C (Baychorov 1980), although this may not be the upper bound for survival (Horan and Lupi 2003). This species can tolerate up to 110 days of ice cover per year (Olenin and Leppäkoski 1999), and is thus expected to have the ability to overwinter within the Great Lakes. The effects of climate change (warming water temperatures) are likely to have a positive effect on this species as compared with Great Lakes native mysids due to its greater degree of adaptation to warm, shallow waters (Bondarenko and Yablonskaya 1979, Ricciardi and Rasmussen 1998).

The range of this species has showed continued expansion throughout the waters of Eastern Europe and Russia over recent decades (Mordukhaĭ-Boltovskoĭ 1979a, Mordukhaĭ-Boltovskoĭ 1979b, Salemaa and Hietalahti 1993, Tarasov 1996), and it has become numerically dominant by biomass in invaded communities (Olenin and Leppäkoski 1999). This species has been intentionally transplanted with great success into many lakes and reservoirs in Eurasia and the Baltic Peninsula, where it has rapidly formed dense populations (Mordukhaĭ-Boltovskoĭ 1964 and 1979a). Current North American ballast water regulations requiring flushing with water of at least 30 ppt have thus far been effective in preventing the establishment of this species in the Great Lakes.

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
	6

- Paramysis lacustris *is recognized as a stenohaline species, typically occurring in salinities of 0-3 PSU (Daneliya 2002, Komarova 1991); however, it has been able to survive short-term salinity exposures of up to 24 PSU (Santagata 2008).*

- *A particular trait of* P. lacustris *that causes increased concern over invasion is its adaptation to water temperatures up to 20°C, while the coldwater mysids already present in the Great Lakes only tolerate temperatures of up to about 10°C (Bondarenko and Yablonskaya 1979).*

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9
Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
	8

- Paramysis lacustris *can tolerate ice cover for periods of up to 110 days per year (Olenin and Leppäkoski 1999).*
- *Within its introduced range in the Curonian Lagoon,* P. lacustris *is likely exposed to water temperatures averaging 0.1–19.3°C (monthly average) (Gasiunaite et al. 2008).*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
	6

- *As an adult,* P. lacustris *is omnivorous, although the diet of immature individuals is considered largely herbivorous. During development, prey shifts from primarily phytoplankton in juveniles to include a larger proportion of mesoplankton in adults, while immature or subadult individuals show mixed diets (Lesutiene et al. 2007).*

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3

Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	0
Unknown	U
	8

- *In waters void of other mysids,* P. lacustris *tends to quickly build dense populations (Olenin and Leppäkoski 1999).*
- *The range of this species has showed continued expansion throughout the waters of Eastern Europe and Russia over recent decades (Mordukhaĭ-Boltovskoĭ 1979a, Mordukhaĭ-Boltovskoĭ 1979b, Salemaa and Hietalahti 1993, Tarasov 1996), and it has become numerically dominant by biomass in invaded communities (Olenin and Leppäkoski 1999).*

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
	U

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
	U

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- *The Great Lakes and Ponto-Caspian region are climatically compatible, which is one of the attributing factors to the success of Ponto-Caspian species in the Great Lakes (Reid and Orlova 2002).*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- *Abiotic factors and climatic conditions in the Ponto-Caspian region are quite similar to the Great Lakes, making the region compatible (Grigorovich et al. 2003, Reid and Orlova 2002).*
- *Great Lakes underwent similar anthropogenic eutrophication as the Ponto-Caspian region (Reid and Orlova 2002). Surface water temperature is similar between the Great Lakes and Ponto-Caspian seas (Grigorovich et al. 2003, Reid and Orlova 2002, USEPA 2008).*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0
Unknown	U
	9

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0
Unknown	U
	6

- *Ponto-Caspian mysids, such as* P. lacustris*, differ greatly from their North American counterparts in their level of adaptation to shallow, warm waters. For instance, the metabolic rate of* P. lacustris *at 20°C is similar to that of cold-water mysids at 10°C (Bondarenko and Yablonskaya 1979).*
- *The effects of climate change (warming water temperatures) are likely to have a positive effect on this species as compared with Great Lakes native mysids due to its greater degree of adaptation to warm, shallow waters (Bondarenko and Yablonskaya 1979, Ricciardi and Rasmussen 1998).*

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
	9

- *Phytoplankton and mesoplankton comprise the diets of juveniles and adults, respectively. Neither of these prey items are limiting within the Great Lakes.*

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being	9

assessed; OR, No, there is no critical species required by the species being assessed	
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Great Lakes and is not likely to be introduced	-80% total points (at end)
Unknown	U
	9

- *There is no critical species required by* P. lacustris.

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes)	6
Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0
Unknown	U
	0

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is	-60% total points (at

suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0
Unknown	U
	U

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9
Frequent, moderate inocula	6
Frequent, small inocula OR infrequent, large inocula	3
Infrequent, small or moderate inocula	0
Unknown	U
	U

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
	9

- *This species has been intentionally transplanted with great success into many lakes and reservoirs in Eurasia and the Baltic Peninsula, where it has rapidly formed dense populations (Mordukhaĭ-Boltovskoĭ 1964, Mordukhaĭ-Boltovskoĭ 1979a).*

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
	9

- *The range of* P. lacustris *has showed continued expansion throughout the waters of Eastern Europe and Russia over recent decades (Mordukhaĭ-Boltovskoĭ 1979a, Mordukhaĭ-Boltovskoĭ 1979b, Salemaa and Hietalahti 1993, Tarasov 1996), and it has become numerically dominant by biomass in the communities into which it has become incorporated (Olenin and Leppäkoski 1999).*

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing the establishment and spread of this species)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent the establishment and/or spread of this species	0
Unknown	U
	0

Establishment Potential Scorecard				
Points	**Probability for Establishment**	A. Total Points (pre-adjustment)		95
>100	High	**Adjustments**		
		B. Critical species	A*(1- 0%)	95
51-99	Moderate	C. Natural enemy	B*(1- 0%)	95
		Control measures	C*(1- 0%)	95
0-50	Low	**Potential for Establishment**		Moderate

# of questions answered as "unable to determine"	Confidence Level		
0-1	High	Total # of questions unknown	4
2-5	Moderate		
6-9	Low	Confidence Level	Moderate
>9	Very low		

Section C: Potential for Impact

IMPACT POTENTIAL RESULTS

Environmental: Moderate

Socio-Economic: Low

Beneficial: Low

***Paramysis lacustris* has the potential for moderate environmental impact if introduced to the Great Lakes.**

Prior to its introduction into the Curonian lagoon, studies showed that *P. lacustris* exhibited preferential feeding on detritus and phytoplankton; its establishment was expected to improve the efficiency of detritus and primary production utilization in the autotrophic waters of the lagoon (Komarova 1991). However, gut samples later taken from introduced individuals revealed a significant proportion of planktonic crustaceans, suggesting active feeding on mesoplankton as opposed to detritus and phytoplankton (Jankauskiene 2003, Lesutiene et al. 2007). Therefore, if introduced to the Great Lakes, this species is expected to cause a zooplankton reduction in areas it invades, leading to spiraling negative effects on planktivorus fish and higher trophic levels (Ricciardi and Rasmussen 1998, Spencer et al. 1991). Hence, *P. lacustris* could potentially become the dominant species in many areas of the Great Lakes currently absent of mysids (Ricciardi and Rasmussen 1998). An expected negative effect of this is the biomagnification of contaminants, such as PCB and mercury, in higher trophic levels due to lengthening of the food chain (Ricciardi and Rasmussen 1998).

In the Baltic Sea, *P. lacustris* has significantly modified invaded habitat through pelletization of the substrate (Olenin and Leppäkoski 1999).

There is little or no evidence to support that *Paramysis lacustris* has the potential for significant socio-economic impacts if introduced to the Great Lakes.

Biomagnification of contaminants in higher trophic levels would likely occur as the result of a lengthening in food chain length where this species invades (Ricciardi and Rasmussen 1998). This would result in higher PCB and mercury levels in pelagic fish, causing potential harm to commercial fisheries. Studies have already shown mercury and PCB levels to be significantly higher in North American mysid-containing lakes as opposed to mysid-free lakes (Cabana et al. 1994, Rasmussen et al. 1990). However, the scale of the resulting economic effects on fisheries is unknown.

There is little or no evidence to support that *Paramysis lacustris* has the potential for significant beneficial effects if introduced to the Great Lakes.

Paramysis lacustris has been recognized as an important food source for many fishes (Ricciardi and Rasmussen 1998), and was intentionally introduced into many lakes and reservoirs in the Baltic Peninsula to support commercial fisheries in the early 1960s (Arbačiauskas 2002, Gasiunas 1964, Komarova 1991, Leppäkoski et al. 2002, Mordukhaĭ-Boltovskoĭ 1964, Mordukhaĭ-Boltovskoĭ 1979a). However, in areas where introduced, the negative impacts of this species have been far more significant than any beneficial effect provided.

POTENTIAL ENVIRONMENTAL IMPACT

NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has resulted in the reduction or extinction of one or more native species populations, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems, etc.)	1 √
Not significantly	0
Unknown	U

- *If introduced to the Great Lakes, this species is expected to cause a zooplankton reduction in areas it invades, leading to spiraling negative effects on planktivorus fish and higher trophic levels (Ricciardi and Rasmussen 1998, Spencer et al. 1991). An expected negative effect of this is the biomagnification of contaminants, such as PCB and mercury, in higher trophic levels due to lengthening of the food chain (Ricciardi and Rasmussen 1998).*
- *Studies have already shown mercury and PCB levels to be significantly higher in North American mysid-containing lakes as opposed to mysid-free lakes (Cabana et al. 1994, Rasmussen et al. 1990).*

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light, etc.)?

Yes, and it has resulted in significant adverse effects (e.g., critical reduction, extinction, behavioral changes, etc.) on one or more native species populations	6
Yes, and it has caused some noticeable stress to or decline of at least one native species population	1
Not significantly	0
Unknown	U √

- Paramysis lacustris *could potentially become the dominant species in many areas of the Great Lakes currently absent of mysids (Ricciardi and Rasmussen 1998).*

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., added pressure to threatened/endangered species, significant reduction or extinction of any native species populations, creation of a dead end or any other significant alteration in the food web, etc.)	6
Yes, and it has resulted in some noticeable stress to or decline of at least one native species population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	1 √
Not significantly	0
Unknown	U

- *Prior to its introduction into the Curonian lagoon, studies showed that* P. lacustris *exhibited preferential feeding on detritus and phytoplankton; its establishment was expected to improve the efficiency of detritus and primary production utilization in the autotrophic waters of the lagoon (Komarova 1991). However, gut samples later taken from introduced individuals revealed a significant proportion of planktonic crustaceans, suggesting active feeding on mesoplankton as opposed to on detritus and phytoplankton (Jankauskiene 2003, Lesutiene et al. 2007).*
- *If introduced to the Great Lakes, this species is expected to cause a zooplankton reduction in areas it invades, leading to spiraling negative effects on planktivorus fish and higher trophic levels (Ricciardi and Rasmussen 1998, Spencer et al. 1991).*

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression, etc.)?

Yes, and it has caused a loss or alteration of genes which may be irreversible or has led to the decline or extinction of one or more native species	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0 √
Unknown	U

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles, etc.)?

Yes, and it has had a widespread, long term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been mild	1
Not significantly	0 √
Unknown	U

Does it alter the physical ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, changes to substrate (physical or chemical), etc.)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1 √
Not significantly	0
Unknown	U

- *In the Baltic Sea,* P. lacustris *has significantly modified invaded habitat through pelletization of the substrate (Olenin and Leppäkoski 1999).*

Environmental Impact Total	**3**
Total Unknowns (U)	**1**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	**<u>Moderate</u>**
0	0-1	Low
1	0	Low
0	≥2	Unknown
1	≥1	Unknown

<u>POTENTIAL SOCIO-ECONOMIC IMPACT</u>

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1
Not significantly	0 √
Unknown	U

S2) Does it cause damage to infrastructure (such as water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1
Not significantly	0 √
Unknown	U

Does it negatively affect water quality?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0 √
Unknown	U

Does it harm any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture, etc.)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

- *Biomagnification of contaminants to higher trophic levels would likely occur as the result of a lengthening in food chain length where this species invades. This would result in higher PCB and mercury levels in pelagic fish, causing potential harm to commercial fisheries (Ricciardi and Rasmussen 1998). However, the scale of the resulting economic effects on fisheries is unknown.*

S5) Does it inhibit recreational activities and/or associated tourism (e.g. through frequent water closures, equipment damage, decline of recreational species, etc.)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

Socio-Economic Impact Total	**0**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**Low**
1	0	
0	≥2	Unknown
1	≥1	

POTENTIAL BENEFICIAL EFFECT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular effect. An "Unknown" response is appropriate if the potential for a particular effect might be inferred but has not been explicitly reported or if there is an unresolved debate about a particular effect.

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1
Not significantly	0 √
Unknown	U

B2) Is it commercially valuable (e.g. for fisheries, aquaculture, agriculture, bait, ornamental trade, etc.)?

Yes, it is economically important to at least one of these industries	6
Yes, but its economic contribution is small	1 √
Not significantly	0
Unknown	U

- Paramysis lacustris *has been recognized as an important food source for many fishes (Ricciardi and Rasmussen 1998), and was intentionally introduced into many lakes and reservoirs in the Baltic Peninsula to support commercial fisheries in the early 1960s (Arbačiauskas 2002, Gasiunas 1964, Komarova 1991, Leppäkoski et al. 2002, Mordukhaĭ-Boltovskoĭ 1964, Mordukhaĭ-Boltovskoĭ 1979a). However, in areas where introduced, the negative impacts of this species have been far more significant than any beneficial effect provided.*

B3) Is it recreationally valuable (e.g. for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local communities and/or tourism	6
It is sometimes employed recreationally, but adds little value to local communities or tourism	1
Not significantly	0 √
Unknown	U

B4) Does the species have some medicinal or research value (outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR It is potentially important to medicine or research and is currently being or scheduled to be studied	1
Not significantly	0 √
Unknown	U

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1
Not significantly	0 √
Unknown	U

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species which is threatened, endangered species, or commercially valuable, etc.)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1
Not significantly	0 √
Unknown	U

Beneficial Effect Total	**1**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**Low**
1	0	
0	≥2	Unknown
1	≥1	

A.8 Crustaceans - Crayfishes

Scientific Name: *Cherax destructor*
Clark, 1936

Common Name: Yabby

Synonyms:

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: Unlikely

Hitchhiking/fouling: Unlikely

Unauthorized intentional release: Moderate

Stocking/planting/escape from recreational culture: Unlikely

Escape from commercial culture: Unlikely

Transoceanic shipping: Low

***Cherax destructor* has a low probability of introduction to the Great Lakes (Confidence level: High).**

Potential pathway(s) of introduction: Unauthorized Intentional Release

Cherax destructor is not currently in waters connecting to the Great Lakes and is not known to be transported through the Great Lakes region. However, it has been increasingly transported globally which could increase the future risk of introduction into the Great Lakes. *Cherax destructor* was originally transported for aquaculture and food, but more recently, it has gained popularity as a pet (Chucholl 2013). Cherax destructor has a relatively high commercial value (Chucholl 2013). When used as bait, unused live bait is often directly discarded in to water (Gherardi 2007). The potential for specimens to be released and become established is extremely high, especially in temperate and warmer climates (Allen and Gherardi 2011).

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100
No, this species does not occur near waters connected to the Great Lakes basin and/or is	0 √

not mobile or able to be transported by wind or water.	
Unknown	U

- Cherax destructor *in naturally found in Australia; it has been found in Victoria, New South Wales, and Southern Queensland (USFWS 2014d).*
- *This species has been introduced to Switzerland, Austria, Netherlands, England, and Germany (Chucholl 2013).*

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0 √
Unknown	U

- *The yabby is usually found buried in the settlement of muddy waters (Withnall 2000).*
- Cherax destructor *is currently a restricted species in Minnesota, Michigan, Illinois, and Ohio.*

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a) Is this species sold at aquarium/pet/garden stores ("brick & mortar" or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100 √
No, this species this species is rarely/never sold.	0
Unknown	U

- Cherax destructor *has a relatively high commercial value (Chucholl 2013).*
- *This species is used as bait, and unused live bait is often being discarded directly into the water (Gherardi 2007).*
- *The Yabby is considered a culinary delicacy Europe and farmed in some countries (e.g. Italy).*
- *Yabby is an aquarium species that is easy to maintain; it can be purchased through e-commerce and is increasingly used in research.*
- *The potential for specimens to be released and become established is extremely high, especially in temperate and warmer climates (Allen and Gherardi 2011).*
- *In 2009,* Cherax destructor *was one of the most popular species in aquarium trade in the Netherlands; popularity was found to have direct link to chance of introduction/establishment (Chucholl 2013).*

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5 √
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1
Unknown	U

- Cherax destructor *is accessible in the United States in areas outside the Great Lakes region. There are none currently found in the Great Lakes region.*
- *Shipping for aquarium trade between the United States and Europe decreased due to crayfish plague, which originated from the crayfish brought from the US; the plague was first recorded in 1859 and removed up to 95% of the indigenous European crayfish species (Chucholl 2013).*
- Cherax destructor *is currently a restricted species in Minnesota, Michigan, Illinois, and Ohio.*
- *It is available for sale online in the United States and could easily be purchased by someone in the Great Lakes region (e.g.,* Ebay *).*
- *They can also be purchased from outside the United States and shipped (e.g.,* Blue Yabby Australia*).*
- *Sixteen online shops offer 37 different nonindigenous crayfish species, including* C. destructor*, and on a scale from very rare to very common, the Yabby was considered a common species to be found in aquariums (Chucholl 2013).*

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0 √
Unknown	U

- *At the time of this assessment, there is no record of* C. destructor *being stocked in close proximity to the Great Lakes.*

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is likely to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces), this activity may occur within 20 km of the basin because of the species' popularity/value.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100
No, this species is not commercially cultured in or transported through the Great Lakes region.	0 √
Unknown	U

- Cherax destructor *is not known to be transported through the Great Lakes region, but its transport has been increasing globally, increasing the future risk of introduction.*
- *This species was originally transported for aquaculture and food, but more recently, it has gained popularity as a pet (Chucholl 2013).*
- *Out of the 600 crayfish species that are found worldwide, the Yabby is one of the few with commercial value (Harlioglu and Harlioglu 2006).*
- *Since the 1970s,* C. destructor *was intentionally introduced into different areas, specifically in Africa and China for aquacultural purposes (Harlioglu and Harlioglu 2006).*

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1

Unknown	U

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100 √
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40
No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0
Unknown	U

- Cherax destructor *has a large tolerance to changing environments (such as temperature, water levels, oxygen levels, and salinity); it can occupy different habitats for a short period of time and can quickly colonize in new environments (USFWS 2014d).*
- *The Yabby has a temperature tolerance of 1-35°C. It stops growing when salinity levels reach 8 ppt and death occurs at 16 ppt. Oxygen levels reaching less than 1 mg/L and a pH range of 7 to 9 can be tolerated (USFWS 2014d).*

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5
Yes, but this species has neither been observed in ballast/fouling ships entering the Great Lakes nor in ports in direct trade with the Great Lakes.	Score x 0.1
No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0 √
Unknown	U

- *There is no evidence at this time showing that there is shipping traffic to the Great Lakes region from waters where the Yabby is present.*
- *Due to the crayfish plague, shipping has been more restricted.*

Vector Potential Scorecard					
Vector		**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind		**0**	x	**0**	Unlikely
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.		**0**	x	**0**	Unlikely
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)		**100**	x 0.5	**50**	Moderate
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)		**0**	x	**0**	Unlikely
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)		**0**	x	**0**	Unlikely
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling		**100**	x 0	**0**	Low
Total Unknowns (U)	**0**	**Confidence Level**		High	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

<u>ESTABLISHMENT POTENTIAL RESULTS</u>

Status: **Not established in North America, including the Great Lakes**

***Cherax destructor* has a moderate probability of establishment if introduced to the Great Lakes (Confidence level: High).**

Since 1932, *Cherax destructor* has become a growing problem. Its original invasion occurred within the Australian continent. Once people started developing an interest in this species, it spread across the globe to Europe and Africa. Wild populations have been established and posed a threat to native crayfish populations and other species.

The biology of the Yabby has aided in its survival. The Yabby has proven to have a high tolerance to many different environments and high fecundity. It also has an aggressive behavior that allows it to compete with other species for food. Cherax destructor does not have many predators in the Great Lakes region nor does it rely on certain species for survival. There are some regulatory measures set in place to prevent the further spread of *C. destructor*.

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
	8

- Cherax destructor *is known to have a high tolerance to a variety of environments.*
- *This species is generally found where there are high oxygen levels and a good source of vegetation (Withnall 2000).*
- *This species' ideal temperature range is 20-25°C, but they are able to survive in 1-35°C while growth stops below 16°C and above 35°C (Withnall 2000).*
- *High salinity levels are tolerated by the Yabby, but only for a period of time. They can survive in sea water for up to 48 hours, but after this stress on their systems, they stop growing (Withnall 2000).*
- *Yabby can tolerate low oxygen levels, but after long periods of time, their growth will stop (Withnall 2000).*
- *The Yabby prefers muddy waters opposed to clear water environments (Withnall 2000), and this species survivse dry periods by burrowing in the mud (Geddes and Smallridge 1993).*
- *They are polytrophic and have high fecundity, which increases their ability to survive (Geddes and Smallridge 1993).*
- *The eggs of* Cherax destructor *were tested and were able to tolerate stress of changes environments, but they were not as harvestable. The conditions they tested were temperature, oxygen levels, salinity, and light (Geddes and Smallridge 1993).*

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9
Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
	7

- Cherax destructor *has a high climate match with the United States, particularly in the East, Texas, and Northwest. A climate match of 0.103 and higher is considered a high match, and the Yabby has a match of 0.388 (USFWS 2014d).*
- *The extreme temperatures near the Great Lakes may affect the growth of the Yabby during some seasons, but their high proliferation would help them survive. They have two spawning events per season and produce approximately 1000 eggs per spawn. Reproduction is linked to water temperature, so the spring and summer would be ideal seasons (Withnall 2000).*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
	8

- *The diet of* C. destructor *is not fully know, but it is known to be an omnivorous species that feeds on plants, detritus, and some arthopods (Allen and Gherardi 2011).*
- *Their diet also switches according to climate. During summer seasons, they tend to eat fish, and in the winter, they eat plants and detritus (USFWS 2014d).*
- Cherax destructor *may have cannibalistic tendencies in areas where there is an overabundance of the species and low levels of natural food sources (Allen and Gherardi 2011).*

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a	0

species in the Great Lakes)	
Unknown	U
	7

- *The Yabby has shown antagonistic behavior to get access to limited resources. In a trial competition between the Yabby and the Marron,* Cherax tenuimanus*, the Yabby won. They concluded that its aggression led to success (Gherardi 2007).*
- *Another crayfish species, Rusty Crayfish or* Orconectes rusticus, *is native to the United States but has invaded Minnesota, Wisconsin, Michigan, Illinois, and other states. Its spread has caused a reduction in the native crayfish population, aquatic plants, and fish populations (University of Minnesota 2009).*
- *The Rusty Crayfish is similar to the yabby because it is a larger crayfish species with an aggressive behavior and an opportunistic diet (University of Minnesota 2009).*
- *The success of the Rusty Crayfish's invasion could give some insight to how the Yabby would compete in the Great Lakes region.*

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
	3

- *The Yabby is polytrophic and have high fecundity which increases their ability to survive (Geddes and Smallridge 1993).*
- *When considering other crayfish species, the Yabby is mostly considered a r-selected species which has characteristics of short life cycles, high fecundity, and fast growth. These are also characteristics of good invaders (Gherardi 2007).*

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0

Unknown	U
	0

- *The reproductive habits of this species is affected by increased day length and water temperature. The eggs rest on the females swimming legs while waiting to hatch (USFWS 2014d).*
- *The seasonal changes in the spring that cause reproduction to begin would be suitable for the Yabby, but its reproductive habits would not affect its ability to become established in the new environment.*

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	5

- Cherax destructor *has a high climate match with the United States, particularly in the East, Texas, and Northwest. A climate match of 0.103 and higher is considered a high match, and the yabby has a match of 0.388 (USFWS 2014d).*
- *When comparing climate conditions of a native region (New South Wales, Australia) to a potential new region in the Great Lakes (Detroit, Michigan) ,there are some similarities and differences. The temperature range in Australia is less drastic than in Michigan, but they reach similar values. In Australia, the average maximum temperature ranges from 63°F to79°F, and the average minimum temperature ranges from 45°F to 66°F. In Michigan, the average maximum temperature ranges from 29°F to 84°F, and the average minimum temperature ranges from 15°F to 63°F. The seasonal changes occur at opposite times with spring being from September to November, summer being from December to February, autumn being from March to May, and winter being from June to August (Australia climate, Michigan climate).*
- *The two locations have similar rainfall measurements but during different months. The most rainfall occurs from January to June in Australia and from May to September in Michigan (Average Australia rainfall, Average Michigan rainfall).*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0

Unknown	U
	7

- C. destructor *is adapted to a wide range of water temperatures, between 1°C and 35°C. It does not grow at water temperatures below 15°C and falls into a state of partial hibernation (i.e. metabolism and feeding cease) when water temperature drops below 16°C (Withnall 2000).*
- *It tolerates high salinities, with growth ceasing at 8 ppt (approximately equal to 25% seawater) and mortalities starting to occur at 16 ppt (Mills and Geddes 1980). It tolerates oxygen concentration <1 mg L^{-1}, being able to survive for a short time at 0 mg L^{-1} oxygen (Mills and Mann 1983, Morrissy and Cassells 1992).*
- *Yabbies are commonly found on muddy or silted bottoms and are rarely found in clear water habitats; they seem to prefer water with moderate levels of turbidity. Possibly, muddy waters afford some protection from predators such as fish and birds, giving the yabby a better chance of survival (Withnall 2000).*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0
Unknown	U
	9

- *The Great Lakes provide an abundant habitat that is suitable for the survival, development, and reproduction of this species.*
- *The Yabby's ideal habitat consists of high oxygen levels and vegetation; they are most likely to be found in swamps, streams, rivers, and dams (Withnall 2000).*
- *This species prefers muddy water and does not need to be fully covered by water unless mating; they require a certain water hardness that comes from dissolved calcium (NSW DPI 2013a).*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0
Unknown	U
	8

- Cherax destructor *may not benefit from the environmental differences, but it is known to have a high tolerance to a variety of environments. (Allen and Gherardi 2011).*
- *The extreme temperatures near the Great Lakes may affect the growth of the Yabby during some seasons, but their high proliferation would help them survive. They have two spawning events per season and produce approximately 1000 eggs per spawn. Reproduction is linked to water temperature, so the spring and summer would be ideal seasons (Withnall 2000).*
- *The Yabby has been the most successful and abundant crayfish in Australian freshwater; it has adapted to the cold waters in the mountains as well as the hot waters of central Australia (NSW DPI 2013a).*

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
	9

- Cherax destructor *is an opportunistic feeder and would be able to find a food source in most environments (Withnall 2000).*
- *The diet of* C. destructor *is not fully known, but it is known to be an omnivorous species that feeds on plants, detritus, and some arthopods (Allen and Gherardi 2011).*
- *Their diet also switches according to climate. During summer seasons, they tend to eat fish, and in the winter, they eat plants and detritus (USFWS 2014d).*

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0

Yes, but the critical species (or one that may provide a similar function) is not present in the Great Lakes and is not likely to be introduced	-80% total points (at end)
Unknown	U
	9

- *At the time of this assessment,* C. destructor *does not have any known organisms that is depends on.*

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes)	6
Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0
Unknown	U
	0

- *There is not currently a species established in the Great Lakes region known to help establish the Yabby.*

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0
Unknown	U
	-10%

- Cherax destructor *prefers to settle in the mud or bottoms of muddy water which acts as protection and aids in survival (Withnall 2000).*
- *Predators are aquatic birds such as Cormorants, Herons and the Ibis, and fish species such as Murray Cod and Callop. Carp compete with Yabbies for food (Withnall 2000).*
- *All three bird species can be found in the Great Lakes region (MSG 2007).*

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9
Frequent, moderate inocula	6
Frequent, small inocula OR infrequent, large inocula	3
Infrequent, small or moderate inocula	0
Unknown	U
	0

- *There have been no introductions of* C. destructor *in the Great Lakes region.*
- *While this species is potentially being sold in the United States, there have been no reports of releases.*
- *There are increased restrictions in areas outside the United States to further prevent their release; in New South Wales Australia, it is illegal to release any crayfish into natural waters without government permission (NSW DPI 2013a).*

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
	7

- Cherax destructor *is naturally found in Australia; it has been found in Victoria, New South Wales, and Southern Queensland (USFWS 2014d).*
- *Its indigenous regions in Australia are South Australia, southern Northern territory, Victoria, and South Australia (Gherardi 2007).*
- *The Yabby was introduced to Western Australia in 1932 by spreading through natural river systems (Gherardi 2007).*
- *It has been introduced to Switzerland, Austria, Netherlands, England, and Germany (Chucholl 2013).*

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
	7

- Cherax destructor *was first moved out of Australia and introduced to Spain in 1983 for commericial reasons and was originally restricted to Spanish waters (Gherardi 2007).*
- *Since then, the Yabby has moved throughout Europe and into Africa and was able to become established as a wild species (Gherardi 2007).*
- *As human interest in crayfish increased, so did the spread of the Yabby (Gherardi 2007).*

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing the establishment and spread of this species)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent the establishment and/or spread of this species	0
Unknown	U
	-40%

- *Regulations have been set to prohibit species in the Great Lakes; the yabby is prohibited in Illinois, Minnesota, and Ohio (GLPANS 2012).*

Establishment Potential Scorecard				
Points	**Probability for Establishment**	A. Total Points (pre-adjustment)		94
>100	High	**Adjustments**		
		B. Critical species	A*(1- 0%)	94

51-99	Moderate	C. Natural enemy	B*(1- 10%)	84.6
		Control measures	C*(1- 50%)	50.8
0-50	Low	**Potential for Establishment**		Moderate
# of questions answered as "unable to determine"	**Confidence Level**			
0-1	High	Total # of questions unknown		0
2-5	Moderate			
6-9	Low	Confidence Level		High
>9	Very low			

Section C: Potential for Impact

IMPACT POTENTIAL RESULTS

Environmental: Moderate

Socio-Economic: Low

Beneficial: Moderate

***Cherax destructor* has the potential for moderate environmental impact if introduced to the Great Lakes.**

Cherax destructor is not known be toxic, parasitic, or poisonous. There have been cases where *C. destructor* has spread diseases and affected indigenous crayfish species. The crayfish plague in 1859 was caused by a parasite, *Aphanomyces astaci*, which was fatal to all European indigenous crayfish. Yabby was a carrier of this parasite (Chucholl 2013). Yabby is also known to carry *Thelohania parastaci* which is a microsporidian disease that causes the destruction of striated and cardiac muscle tissue and eventually leads to death of the affected crayfish (Gherardi 2007).

There is little or no evidence to support that *Cherax destructor* has the potential for significant socio-economic impacts if introduced to the Great Lakes.

It has not been reported that *Cherax destructor* poses a threat to human health or water quality. There is no evidence that this species negatively impacts infrastructure, economic sectors, recreational activities and associated tourism, or the aesthetic appeal of the areas it inhabits.

***Cherax destructor* has the potential for moderate beneficial impact if introduced to the Great Lakes.**

Cherax destructor has commercial value but its economic contribution is small. It is sometimes employed recreationally, but adds little value to local communities or tourism.

POTENTIAL ENVIRONMENTAL IMPACT

NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1 √
Not significantly	0
Unknown	U

- Cherax destructor *is not known be toxic, parasitic, or poisonous.*
- *There have been cases where* C. destructor *has spread diseases and affected indigenous crayfish species.*
- *The crayfish plague in 1859 was caused by a parasite,* Aphanomyces astaci*, which was fatal to all European indigenous crayfish. The Yabby was a carrier of this parasite. (Chucholl 2013)*
- *The Yabby is also known to carry* Thelohania parastaci *which is a microsporidian disease that causes the destruction of striated and cardiac muscle tissue and eventually leads to death of the affected crayfish. (Gherardi 2007)*

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1 √
Not significantly	0
Unknown	U

- C. destructor *has the ability to switch trophic positions, when an otherwise abundant, high protein food sources (i.e. fish) becomes limited. Furthermore, the ability of* C. destructor *to switch from a diet of fish in summer to a predominantly herbaceous/detrital diet in winter suggests that it may compete for food resources with the other smaller native freshwater crayfishes in Australia (Beatty 2005).*

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in the food web)	6
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the	1

effects of which have not been widespread or severe	
Not significantly	0
Unknown	U √

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0 √
Unknown	U

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1
Not significantly	0
Unknown	U √

- *Burrowing activity of the Yabby may increase turbidity.*

E6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1
Not significantly	0
Unknown	U √

- *Burrowing activity of the Yabby may increase erosion/siltation.*

Environmental Impact Total	**2**
Total Unknowns (U)	**3**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	**Moderate**
0	0-1	Low
1	0	
0	≥2	Unknown
1	≥1	

POTENTIAL SOCIO-ECONOMIC IMPACT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1
Not significantly	0 √
Unknown	U

S2) Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1 √
Not significantly	0
Unknown	U

- *The burrowing behaviour of C. destructor is a cause for concern for farmers. Yabbies are capable of digging very deep burrows which can be 50 cm to 2 meters deep depending on the species. Burrows are connected by access shafts to the water. In the event of the water drying up, the yabby is able to survive over summer in the burrows. Unfortunately, this behaviour may also destroy the integrity of dam walls causing problems for farmers (Withnall 2000).*

S3) Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0 √

Unknown	U

S4) Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

Socio-Economic Impact Total	**1**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**Low**
1	0	
0	≥2	Unknown

1	≥1	

POTENTIAL BENEFICIAL EFFECT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular effect. An "Unknown" response is appropriate if the potential for a particular effect might be inferred but has not been explicitly reported or if there is an unresolved debate about a particular effect.

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1
Not significantly	0 √
Unknown	U

B2) Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?

Yes, it is economically important to at least one of these industries	6
Yes, but its economic contribution is small	1 √
Not significantly	0
Unknown	U

- *This is a popular species for aquaculture for purposes of eating and using in aquaria (NSW DPI 2013a).*

B3) Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local communities and/or tourism	6
It is sometimes employed recreationally, but adds little value to local communities or tourism	1 √
Not significantly	0
Unknown	U

- *This is a popular species for recreational "catching" for purposes of eating and using as bait or in aquaria (NSW DPI 2013a).*

B4) Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR	1

It is potentially important to medicine or research and is currently being or scheduled to be studied	
Not significantly	0 √
Unknown	U

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1
Not significantly	0 √
Unknown	U

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1
Not significantly	0 √
Unknown	U

Beneficial Effect Total	**2**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	**<u>Moderate</u>**
0	0-1	Low
1	0	
0	≥2	Unknown
1	≥1	

A.9 Crustaceans - Crabs

Scientific Name: *Rhithropanopeus harrisii*
(Gould, 1841)

Common Name: Harris Mud Crab, Estuarine Mud Crab, Dwarf Mud Crab, White-fingered (or white-tipped) Mud Crab

Synonyms: *Pilumnus tridentatus* Maitland, 1874; *Heteropanope tridentata* De Man, 1892; *Pilumnopeus tridentatus* Balss,1933; *Pilumnus harrisii* Gould, 1841; *Rhithropanopeus harrisii* ssp. *tridentatus* Buitendijk & Holthuis, 1949; *Panopeus wurdemannii* Gibbes, 1850

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: Unlikely

Hitchhiking/fouling: Low

Unauthorized intentional release: Unlikely

Stocking/planting/escape from recreational culture: Unlikely

Escape from commercial culture: Unlikely

Transoceanic Shipping: Moderate

***Rhithropanopeus harrisii* has a moderate probability of introduction to the Great Lakes (Confidence level: High).**

Potential pathway(s) of introduction: Hitchhiking/Fouling, Transoceanic Shipping

Introduction of Gulf of Mexico populations of *Rhithropanopeus harrisii* into inland **Texas** reservoirs may have occurred through bait bucket or accidental angler and boater release (Howells 2001). *Rhithropanopeus harrisii* has been found in ten freshwater impoundments in Texas (Boyle et al. 2010). While this species could arrive in the Great Lakes via ballast or hitchhiking/fouling, it seems more likely that a population able to establish in freshwater would arrive via hitchhiking/fouling from the Texan reservoirs, as these populations are already adapted to freshwater. While recreational boat traffic does occur between Texas and the Great Lakes (Davidson pers. observation), the frequency would likely be very low given the distance.

A gravid *R. harrisii* female has been found in ships arriving from coastal traffic to east Canadian ports following mid-ocean ballast exchange (Briski et al. 2012). Female *R. harrisii* individuals are able to release fertilized egg clutches up to four separate times following a single mating. Multiple spawnings may also assure continued reproduction under stressful or hazardous conditions, when mating activity may be reduced (Morgan et al. 1983). *Rhithropanopeus harrisii* larvae can detect vertical gradients in temperature, salinity, and hydrostatic pressure, which are used for depth regulation and avoidance of adverse environmental conditions (Forward 2009). Thus this species is highly like to survive transit in ballast tanks and reproduce enroute.

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100
No, this species does not occur near waters connected to the Great Lakes basin and/or is not mobile or able to be transported by wind or water.	0 √
Unknown	U

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100 √
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0
Unknown	U

- *Introduction of Gulf of Mexico populations of* R. harrisii *into inland Texas reservoirs may have occurred through bait bucket or accidental angler and boater release (Howells 2001).*
- *Boaters travel between Texas and Great Lakes waters (Davidson pers. observation).*

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5

This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1 √
Unknown	U

- Rhithropanopeus harrisii *has been found in ten freshwater impoundments in Texas (Boyle et al. 2010).*

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a) Is this species sold at aquarium/pet/garden stores ("brick & mortar" or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100
No, this species this species is rarely/never sold.	0 √
Unknown	U

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0 √
Unknown	U

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is <u>likely</u> to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal	Score x 0.25

or state regulations in more than half the basin (> 5 states/provinces), this activity <u>may</u> occur within 20 km of the basin because of the species' popularity/value.	
Unknown	U

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100
No, this species is not commercially cultured in or transported through the Great Lakes region.	0 √
Unknown	U

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100 √
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40
No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0
Unknown	U

- *A gravid* R. harrisii *female has been found in ships arriving from coastal traffic to east Canadian ports following mid-ocean ballast exchange (Briski et al. 2012).*
- *Female* R. harrisii *individuals are able to release fertilized egg clutches up to four separate times following a single mating. Multiple spawnings may also assure continued reproduction under stressful or hazardous conditions, when mating activity may be reduced (Morgan et al. 1983).*
- Rhithropanopeus harrisii *larvae can detect vertical gradients in temperature, salinity, and hydrostatic pressure, which are used for depth regulation and avoidance of adverse environmental conditions (Forward 2009).*

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5 √
Yes, but this species has neither been observed in ballast/fouling ships entering the Great Lakes nor in ports in direct trade with the Great Lakes.	Score x 0.1
No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0
Unknown	U

- *The native range of* R. harrisii *extends along the Atlantic coast of North America, from the southern Gulf of Saint Lawrence, Canada to Veracruz in the Gulf of Mexico (Williams 1984).*
- Rhithropanopeus harrisii *is present in many European waters, including the Baltic Sea and North Sea (GISD 2008).*

Vector Potential Scorecard				
Vector	**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind	**0**	x	**0**	Unlikely
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.	**100**	x 0.1	**10**	Low
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)	**0**	x	**0**	Unlikely
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)	**0**	x	**0**	Unlikely
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)	**0**	x	**0**	Unlikely
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling	**100**	x 0.5	**50**	Moderate
Total Unknowns (U)	**0**	**Confidence Level**	High	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

ESTABLISHMENT POTENTIAL RESULTS

Status: **Established in North America, but not the Great Lakes**

Rhithropanopeus harrisii **has a high probability of establishment if introduced to the Great Lakes (Confidence level: High).**

This species inhabits areas with climates similar to the Great Lakes (e.g., mid-Atlantic and northern European climates have hot summers, cold winters and significant rainfall). Water temperatures in inhabited areas include the range of Great Lakes temperatures, e.g., highs in the Panama Canal (up to 30.3°C) (Roche et al. 2009), and lows in the Miramichi Estuary, Canada (near freezing for up to six months of the year) (Chadwick 1995). While much previous literature describes *Rhithropanopeus harrisii* as intolerant of freshwater conditions, populations have recently been found in near-freshwater conditions. This species is likely to tolerate suboptimal conditions including a wide range of salinity, temperature and oxygen depletion. This species inhabits polluted areas, including the Baltic Sea, which is heavily polluted (though improvements have been made) (Glasby and Szefer 1998). The ability to tolerate high salinities may give *R. harrisii* a competitive edge over native species in areas polluted by road salt. *R. harrisii* is able to reproduce when the water temperature is above 14°C (Turoboyski 1973). The Mud Crab thrives on a diverse diet of plants and animals, including Zebra Mussels (*Dreissena polymorpha*) and will likely find plenty to eat in the Great Lakes ecosystems.

R. harrisii is parasitized and sterilized by the rhizocephalan parasite *Loxothylaxus panopaei* in saline environments. Larvae of *L. panopaei* survive poorly at salinities below 10 ppt (Forward 1991, Reisser and Forward 1991) which may release the freshwater populations from control by this parasite.

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
	8

- *While much previous literature describes* R. harrisii *as intolerant of freshwater conditions, populations have recently been found in near-freshwater conditions.*
- R. harrisii *populations have been found well-established (metamorphosis and reproduction) in Tradinghouse Creek reservoir (Texas), which has a salinity of 0.4-0.5 ppt (Boyle et al. 2010).*
- *High percentage of eggs from these Texan reservoirs hatched in lab at salinity of 0.5 ppt (Richey 2004).*
- R. harrisii *is well established and successfully reproducing in the Northern Lagoon (Panama), with constantly recorded salinities between 0.4% and 0.6% (Roche et al. 2009).*
- *Reasons for freshwater tolerance (where none had been found before) include (Boyle et al. 2010):*
    1. *Source population is more tolerant to low salinity. Texas populations may be from Florida and/or Gulf of Mexico populations, which show greater tolerance to low salinity (Richey 2004). Louisiana populations are genetically distinct from American East Coast and Europe populations (Projecto-Garcia et al. 2010).*
    2. *Tolerance to freshwater is a recent result of natural selection, based on the ability of a small number of individuals. This ability was not detected previously in laboratory studies due to small sample size.*

- *Wurtz and Roback (1955) found species in rivers emptying into the Gulf of Mexico in salinities from 0.006 to 22.6 ppt (Costlow et al. 1966).*
- *Larvae develop in salinities up to 40 ppt (Costlow et al. 1966).*
- *In its introduced range in Poland,* R. harrisii *is able to reproduce when the water temperature is above 14°C (Turoboyski 1973); larvae develop at temperatures below 30°C (Costlow et al. 1966).*
- *Since zoeae are retained in estuaries, they develop in a highly variable environment. Accordingly, they can complete development in a very wide range of temperatures and salinities (Forward 2009).*
- *Reid et al. (2007) and Klein et al. (2010) measured rapid declines in dissolved oxygen concentration inside ballast tanks to 2 mg/L within 5 to 7 days, with 90% of initial oxygen content lost within 10 days at temperatures above 20°C. A gravid* R. harrisii *female survived 5 days in ballast water with temperatures often over 20°C (Briski et al. 2012), thus indicating this species is likely to tolerate suboptimal conditions.*

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9
Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
	8

- *Turoboyski (1973) reported that populations in the Vistula River, Poland could survive winter temperatures below 1°C and could even survive being frozen in ice for a short time. This is not particularly unusual as populations at the northern edge of their natural range in the Miramichi Estuary, Canada are exposed to salt water near freezing for up to six months of the year (Chadwick 1995, Fowler et al. 2013).*
- *Has been recorded in water with DO of 0.554 mg/L (Turoboyski 1973).*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
	9

- *The mud crab feeds on both plants and animals, the proportions between these two major components differing between areas (Kujawa 1957, Turoboyski 1973). For example, while the mud crabs dwelling in the Vistula Lagoon fed mainly on* Dreissena polymorpha*, the major food items in the Dead Vistula included* Nereis diversicolor, Mytilus edulis*, and* Cordylophora caspia*, as well as the algae* Cladophora *sp. and* Enteromorpha *sp. The Odra estuary population was found to feed mainly on detritus, which accounted for 61.1 % of the gut content; the animal food items, making up 12.9% of the contents, contained remains of appendages of copepods and insects, as well as fragments of the Blue Mussel (*M. edulis*) and the Zebra Mussel (*D. polymorpha*) (Czerniejewski and Rybczyk 2008).*

- *The type of food consumed has been found to be significantly (P<0.05) dependent on the locality inhabited: the greater the biodiversity of the habitat, the richer the dietary composition. In Baltic coastal waters this species feeds on detritus, and also on animal and plant matter. Remains of Chlorophyta, Amphipoda, Ostracoda, Polychaeta, Gastropoda and Bivalvia were found in the stomachs of the specimens analysed (Hegele-Drywa and Normant 2009).*

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	0
Unknown	U
	U

- R. harrisii *one of the most important benthic species in the Vistula lagoon (Baltic Sea), where it is non-native (Ezhova et al. 2005).*
- *The* R. harrisii *appears to occupy the same niche as crayfish, which means it could be easily displaced if* R. harrisii *is the better competitor. Observations over the past three summers at Possum Kingdom have indicated an abundance of crabs and a paucity of crayfish (Richey 2004).*

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
	5

- *Typically produces 1000-4000 eggs, up to 7500 eggs per clutch (Morgan et al. 1983).*
- *For 5 species in infraorder Brachyura (Rodgers et al. 2011):*
  - Eurypanopeus depressus*: 2,263 eggs/brood (SE 1,021); 2 broods/year; 4.5 x 10^3 eggs/year*
  - R. harrisii*: 1,901 eggs/brood (SE 532); 4 broods/year; 7.6 x 10^3 eggs/year*
  - Pachygrapsus transversus*: 4,935 eggs/brood (SE 908); unknown broods/year and eggs/year*
  - Uca beebei*: 4,028 eggs/brood (SE 1,192); 5 broods/year; 2.0 x 10^4 eggs/year*
  - U. terpsichores*: 6,016 eggs/brood (SE 966); 5 broods/year; 3.0 x 10^4 eggs/year*

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
	5

- *Females of* R. harrisii *are able to release fertilized egg clutches up to four separate times following a single mating. Multiple spawnings may also assure continued reproduction under stressful or hazardous conditions, when mating activity may be reduced. (Morgan et al. 1983).*
- R. harrisii *is parasitized and sterilized by the rhizocephalan parasite Loxothylaxus panopaei in saline environments. Larvae of L. panopaei survive poorly at salinities below 10 ppt (Forward 2009, Reisser and Forward 1991).*
- *After* R. harrisii *megalopae settle out in a suitable habitat, they quickly grow to reproductive size.* R. harrisii *is physiologically able to reproduce by the fifth crab stage (Payen 1975), which takes only a month to attain after metamorphosis at 25°C (Morgan et al. 1983).*

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	6

- *This species inhabits areas with climates similar to the Great Lakes. E.g., mid-Atlantic and northern European climates have hot summers, cold winters and significant rainfall.*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- *This species inhabits polluted areas, including the Baltic Sea, which is heavily polluted (though improvements have been made) (Glasby and Szefer 1998).*
- *Water temperatures in inhabited areas of* R. harrisii *include the range of Great Lakes temperatures, e.g., highs in the Panama Canal (up to 30.3°C) (Roche et al. 2009), and lows in the Miramichi Estuary, Canada (near freezing for up to six months of the year) (Chadwick 1995).*
- *Lives in salinities of 0.4-0.5 ppt (Boyle et al. 2010).*
- *Live in pH range of 5.4-7.8 (Roche et al. 2009).*
- *Baltic Sea has received heavy nutrient inputs from agricultural land and is mesotrophic (Glasby and Szefer 1998); native habitat includes the eutrophic Gulf of Mexico.*
- *Inhabits areas with no current (Texan reservoirs) and areas with current (Eider, Elbe, Ems, and Weser Rivers) (Jensen 2010).*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0
Unknown	U
	9

- *In Texan reservoirs, habitat of* R. harrisii *includes sand and gravel mix with a few stones for cover (Richey 2004).*
- *In the Baltic Sea, this species can opportunistically occupy extremely diverse habitats, such as shafts of dead marsh plants, self-made burrows in muddy bottoms, under small stones along the shore, and the brown algae Fucus vesiculosus in hard bottoms sometimes exposed to heavy wind and waves, up to 37 m depth (Fowler et al. 2013).*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6

Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0
Unknown	U
	9

- *This species is highly adaptable, and can survive in a wide range of temperatures, as well as salinities. The ability to tolerate high salinities may give* R. harrisii *a competitive edge to native species.*

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
	9

- R. harrisii *feeds on both plants and animals, the proportions between these two major components differing between areas (Kujawa 1957, Turoboyski 1973). For example, while* R. harrisii *dwelling in the Vistula Lagoon fed mainly on* Dreissena polymorpha*, the major food items in the Dead Vistula included* Nereis diversicolor*,* Mytilus edulis*, and* Cordylophora caspia*, as well as the algae* Cladophora *sp. and* Enteromorpha *sp. The Odra estuary population was found to feed mainly on detritus, which accounted for 61.1 % of the gut content; the animal food items, making up 12.9% of the contents, contained remains of appendages of copepods and insects, as well as fragments of the Blue Mussel (*M. edulis*) and the Zebra Mussel (*D. polymorpha*) (Czerniejewski and Rybczyk 2008).*
- *The type of food consumed has been found to be significantly (P<0.05) dependent on the locality inhabited: the greater the biodiversity of the habitat, the richer the dietary composition. In Baltic coastal waters this species feeds on detritus, and also on animal and plant matter. Remains of Chlorophyta, Amphipoda, Ostracoda, Polychaeta, Gastropoda, and Bivalvia were found in the stomachs of the specimens analysed (Hegele-Drywa and Normant 2009).*

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9

Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Great Lakes and is not likely to be introduced	-80% total points (at end)
Unknown	U
	9

- *There are no critical species required by* R. harrisii.

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes)	6
Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0
Unknown	U
	5

- R. harrisii *is significantly more abundant in non-native* Phragmites australis *than in native* Spartina alterniflora *(Able and Hagan 2000).*
- *In 2001-2004, large numbers of young crabs have been recorded inhabiting aggregations of* Dreissena polymorpha *in the Vistula Lagoon. Colonies of this common Ponto-Caspian bivalve invader apparently serve as a perfect hiding place for these crabs (Grabowski et al. 2005).*

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	-80% total points (at end)

Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0
Unknown	U
	0

- *Larvae have several safeguards against predation: they undergo nocturnal diel vertical migration (DVM) and have a shadow response to avoid encountering predators, and they bear long spines as a deterrent (Forward 2009).*

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9
Frequent, moderate inocula	6
Frequent, small inocula OR infrequent, large inocula	3
Infrequent, small or moderate inocula	0
Unknown	U
	0

- *While this species could arrive via ballast or hitchhiking/fouling, it seems more likely that a population able to establish in freshwater would arrive via hitchhiking/fouling from the Texan reservoirs, as these populations are already adapted to freshwater. While recreational boat traffic does occur between Texas and the Great Lakes (Davidson pers. observation), the frequency would likely be very low given the distance.*

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0

Unknown	U
	9

- *The native range of R. harrisii extends along the Atlantic coast of North America, from the southern Gulf of Saint Lawrence, Canada to Veracruz in the Gulf of Mexico (Williams 1984).*
- R. harrisii *has invaded over 20 countries, two oceans, ten seas, and ten freshwater inland reservoirs across four continents, which span over 45 degrees of latitude, most likely due to anthropogenic means (Roche and Torchin 2007).*
- *Adriatic Sea, Aral Sea, Azerbaijan, Azov Sea, Baltic Sea, Belgium, Black Sea, Britain, Bulgaria, Caspian Sea, Denmark, France, Germany, Iran, Italy, Kazakhstan. Lithuania, Mediterranean Sea, Netherlands, North Sea, Panama Canal, Poland, Portugal, Romania, Russia, Spain, Tunisia, Turkmenistan, Ukraine, Uzbekistan, Pacific Coast and Texas lakes of United States (GISD 2008).*

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
	6

- *The first European record of* R. harrisii *dates back to before 1874 when it was described as a new species from the Zuiderzee in the Netherlands (Wolff 2005). The first German record is from 1936 in the Kiel Canal connecting the North and Baltic Seas (Gollasch and Nehring 2006, Nehring 2000). It first appeared on the Baltic coast of Germany between 1948 and 1950. Since then it has spread to estuaries of several rivers, including the Eider, Elbe, Ems, Weser and on a few occasions even the German section of the Rhine. The increase in abundance has taken place chiefly during the 1990s (Nehring 2000). There are a few Danish records from the harbour of Copenhagen in 1953 and 1954 (Rasmussen 1958). The next record is from 2008, just south of Copenhagen, but recently* R. harrisii *has become established in south-eastern Denmark (Olesen and Tendal 2009). In the Baltic it has been found in Poland since 1951 (Grabowski et al. 2005, Normant et al. 2004) and in Lithuania since 2000 (Bacevičius and Gasiūnaitė 2008). In France it first appeared in 1955-1956 (Goulletquer et al. 2002), in Portugal in 1989 (Gonçalves et al. 1995), and in Spain in 1990 (Roche and Torchin 2007). In the United Kingdom, R. harrisii only occurs in one locality, Cardiff Docks in Wales, where it was first found in 1996 (Eno et al. 1997, Jensen 2010).*
- *This species was first reported in Finland in 2009 from the archipelago close to Turku and has been found from 82 locations within a 30 km radius in 2012 (Fowler et al. 2013).*

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing the establishment and spread of this species)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species.	-50% total

(There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent the establishment and/or spread of this species	0
Unknown	U
	0

- *There are no existing control measures to prevent establishment or spread of this species.*

Establishment Potential Scorecard				
Points	**Probability for Establishment**	A. Total Points (pre-adjustment)		105
>100	High	**Adjustments**		
		B. Critical species	A*(1- 0%)	105
51-99	Moderate	C. Natural enemy	B*(1- 0%)	105
		Control measures	C*(1- 0%)	105
0-50	Low	**Potential for Establishment**		High
# of questions answered as “unable to determine”	**Confidence Level**			
0-1	High	Total # of questions unknown		1
2-5	Moderate			
6-9	Low	Confidence Level		High
>9	Very low			

Section C: Potential for Impact

IMPACT POTENTIAL RESULTS

Environmental: Unknown

Socio-Economic: Low

Beneficial: Low

There is little or no evidence to support that *Rhithropanopeus harrisi* has the potential for significant environmental impacts if introduced to the Great Lakes.

R. harrisii commonly carry strains of the white spot baculovirus (Payen and Bonami 1979) While impact studies are scarce, Fowler et al. (2013) predicts that regarding the introduction of this species in Finland, alterations to the benthic community are expected, as it is a completely new functional species to that area. The Mud Crab appears to occupy the same niche as crayfish, which means crayfish species could be displaced if the mud crab is the better competitor. Observations from 2000-2003 at Possum Kingdom have indicated an abundance of crabs and a paucity of crayfish (Richey 2004). Declines in Aral Sea biodiversity are in part attributed to introduction of alien species such as *R. harrisii* (Aladin and Potts 1992). A number of coastal mud crabs (Xanthidae, Panopew and other genera) are reported as major predators on young oysters and hard clams (Gosner et al. 1979). *R. harrisii* may have a negative impact upon local unionid populations, but this remains to be determined (Howells 1992). *R. harrisii* likely plays a minor role in reduction of *Crassostrea virginica* spat (Kulp et al. 2011). Along with *M. viridis* and *P. antipodarum, R. harrisii* has contributed to habitat modification (Ezhova et al. 2005).

Current research on the potential for socio-economic impacts to result from *Rhithropanopeus harrisi* if introduced to the Great lakes is inadequate to support proper assessment.

In Texas, the crab has become very abundant in almost freshwater reservoirs and is reported to foul PVC intakes in lakeside homes (Richey 2004). In the Caspian Sea, where it has reached very high densities, the crab causes economic loss to fishermen by spoiling fishes in gill nets (Zaitsev and Öztürk 2001).

Current research on the potential for beneficial impacts to result from *Rhithropanopeus harrisi* if introduced to the Great lakes is inadequate to support proper assessment.

R. harrisii larvae have been used for a variety of toxicology studies to identify lethal and sublethal concentrations. The attributes of *R. harrisii* for these studies are that (1) the larvae are easy to rear in the laboratory with low mortality; (2) they are robust and can complete development in a wide range of temperatures and salinities; and (3) since they are retained in estuaries, they would be exposed to land runoff that could contain pesticides, herbicides, and other potential toxicants (Forward 2009). This species can consume *Dreissena polymorpha* (Kujawa 1957) but the degree of its potential impact on Dreissenid populations is unknown.

<u>POTENTIAL ENVIRONMENTAL IMPACT</u>

NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1
Not significantly	0
Unknown	U √

- *R. harrisii commonly carry strains of the white spot baculovirus (Payen and Bonami 1979).*

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1
Not significantly	0
Unknown	U √

- *While impact studies are scarce, Fowler et al. (2013) predicts that regarding the introduction of this species in Finland, alterations to the benthic community are expected, as it is a completely new functional species to that area.*
- *The Mud Crab appears to occupy the same niche as crayfish, which means it could be displaced if the mud crab is the better competitor. Observations from 2000-2003 at Possum Kingdom have indicated an abundance of crabs and a paucity of crayfish (Richey 2004).*
- *Declines in Aral Sea biodiversity are in part attributed to introduction of alien species such as* R. harrisii *(Aladin and Potts 1992).*

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in the food web)	6
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	1
Not significantly	0
Unknown	U √

- *A number of coastal mud crabs (Xanthidae, Panopew and other genera) are reported as major predators on young oysters and hard clams (Gosner 1979).* R. harrisii *may have a negative impact upon local unionid populations, but this remains to be determined (Howells 1992).*
- R. harrisii *likely plays a minor role in reduction of Crassostrea virginica spat (Kulp et al. 2011).*

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0 √
Unknown	U

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1
Not significantly	0 √
Unknown	U

E6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1
Not significantly	0
Unknown	U √

- *Along with M. viridis and P. antipodarum, R. harrisii has contributed to habitat modification (Ezhova et al. 2005).*

Environmental Impact Total	**0**
Total Unknowns (U)	**4**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	Low
1	0	
0	≥2	**Unknown**
1	≥1	

POTENTIAL SOCIO-ECONOMIC IMPACT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1
Not significantly	0 √
Unknown	U

S2) Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1√
Not significantly	0
Unknown	U

- *In Texas, the crab has become very abundant in almost freshwater reservoirs and is reported to foul PVC intakes in lakeside homes (Richey 2004).*

S3) Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0 √
Unknown	U

S4) Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

- *In the Caspian Sea, where it has reached very high densities, the crab causes economic loss to fishermen by spoiling fishes in gill nets (Zaitsev and Öztürk 2001).*

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

Socio-Economic Impact Total	**1**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**Low**
1	0	
0	≥2	Unknown
1	≥1	

POTENTIAL BENEFICIAL EFFECT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular effect. An "Unknown" response is appropriate if the potential for a particular effect might be inferred but has not been explicitly reported or if there is an unresolved debate about a particular effect.

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1
Not significantly	0 √
Unknown	U

B2) Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?

Yes, it is economically important to at least one of these industries	6
Yes, but its economic contribution is small	1
Not significantly	0 √
Unknown	U

B3) Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local communities and/or tourism	6
It is sometimes employed recreationally, but adds little value to local communities or tourism	1
Not significantly	0 √
Unknown	U

B4) Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR It is potentially important to medicine or research and is currently being or scheduled to be studied	1 √
Not significantly	0
Unknown	U

- R. harrisii *larvae have been used for a variety of toxicology studies to identify lethal and sublethal concentrations. The attributes of R. harrisii for these studies are that (1) the larvae are easy to rear in the laboratory with low mortality; (2) they are robust and can complete development in a wide range of temperatures and salinities; and (3) since they are retained in estuaries, they would be exposed to land runoff that could contain pesticides, herbicides, and other potential toxicants (Forward 2009).*

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1

Not significantly	0 √
Unknown	U

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1
Not significantly	0 √
Unknown	U

Beneficial Effect Total	**1**
Total Unknowns (U)	**0**

<table>
<tr><th colspan="3">Scoring</th></tr>
<tr><th>Score</th><th># U</th><th>Impact</th></tr>
<tr><td>>5</td><td>Any</td><td>High</td></tr>
<tr><td>2-5</td><td>Any</td><td>Moderate</td></tr>
<tr><td>0</td><td>0-1</td><td rowspan="2"><u>Low</u></td></tr>
<tr><td>1</td><td>0</td></tr>
<tr><td>0</td><td>≥2</td><td rowspan="2">Unknown</td></tr>
<tr><td>1</td><td>≥1</td></tr>
</table>

Scientific Name: ***Sinelobus stanfordi***
(Richardson, 1901)

Common Name:

Synonyms:

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: Unlikely

Hitchhiking/fouling: Low

Unauthorized intentional release: Unlikely

Stocking/planting/escape from recreational culture: Unlikely

Escape from commercial culture: Unlikely

Transoceanic shipping: Moderate

***Sinelobus standfordi* has a moderate probability of introduction to the Great Lakes (Confidence level: High).**

Potential pathway(s) of introduction: Transoceanic Shipping

Transport in ballast water is a likely vector responsible for the arrival of *S. stanfordi* in the Netherlands (van Haaren and Soors 2009). *Sinelobus stanfordi* has been collected in Argentina, Brazil, Uruguay, West Indies, Florida (Coral Gables Waterway), Galapagos, Sri Lanka, Sudan, South Africa (Gardiner 1975); Mexico (Hendrickx and Ibarra 2008); British Columbia (Levings and Rafi 1978); Dutch and Belgian North Sea coast, including port of Antwerp (van Haaren and Soors 2009); San Francisco Bay and delta (Cohen and Carlton 1995); Lower Colombia River and Coos Bay, Oregon (Ruiz et al. 2000, Sytsma et al. 2004), South Carolina (SC DNR 2008), and Washington (Joyce 2005, van Haaren and Soors 2009).

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100
No, this species does not occur near waters connected to the Great Lakes basin and/or is not mobile or able to be transported by wind or water.	0 √
Unknown	U

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100 √
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0
Unknown	U

- *Fouling is a likely vector responsible for the arrival of* S. stanfordi *in the Netherlands (van Haaren and Soors 2009).*

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1 √
Unknown	U

- Sinelobus stanfordi *is present in Florida (Coral Gables Waterway) (Gardiner 1975); San Francisco Bay and delta (Cohen and Carlton 1995); Lower Colombia River and Coos Bay, Oregon (Ruiz et al. 2000, Sytsma et al. 2004), South Carolina (South Carolina Department of Natural Resources 2008), and Washington (Joyce 2005, van Haaren and Soors 2009).*

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a) Is this species sold at aquarium/pet/garden stores ("brick & mortar" or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100

No, this species this species is rarely/never sold.	0 √
Unknown	U

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0 √
Unknown	U

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is likely to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces), this activity may occur within 20 km of the basin because of the species' popularity/value.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100
No, this species is not commercially cultured in or transported through the Great Lakes region.	0 √

Unknown	U

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100 √
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40
No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0
Unknown	U

- *Transport in ballast water is a likely vector responsible for the arrival of* S. stanfordi *in the Netherlands (van Haaren and Soors 2009).*
- Sinelobus stanfordi *can withstand huge fluctuations in salinity. This species is able to survive these fluctuations presumably by active control of the osmotic concentration of the body fluids (Kikuchi and Matsumasa 1993, van Haaren and Soors 2009).*

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5 √
Yes, but this species has neither been observed in ballast/fouling ships entering the Great	Score x 0.1

Lakes nor in ports in direct trade with the Great Lakes.	
No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0
Unknown	U

- Sinelobus stanfordi *has been collected in Argentina, Brazil, Uruguay, West Indies, Florida (Coral Gables Waterway), Galapagos, Sri Lanka, Sudan, South Africa (Gardiner 1975); Mexico (Hendrickx and Ibarra 2008); British Columbia (Levings and Rafi 1978); Dutch and Belgian North Sea coast, including port of Antwerp (van Haaren and Soors 2009); San Francisco Bay and delta (Cohen and Carlton 1995); Lower Colombia River and Coos Bay, Oregon (Ruiz et al. 2000, Sytsma et al. 2004), South Carolina (SC DNR 2008), and Washington (Joyce 2005, van Haaren and Soors 2009).*

Vector Potential Scorecard				
Vector	**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind	**0**	x	**0**	Unlikely
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.	**100**	x 0.1	**10**	Low
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)	**0**	x	**0**	Unlikely
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)	**0**	x	**0**	Unlikely
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)	**0**	x	**0**	Unlikely
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling	**100**	x 0.5	**50**	Moderate
Total Unknowns (U)	**0**	**Confidence Level**	High	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	**Confidence Level**

0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

ESTABLISHMENT POTENTIAL RESULTS

Status: **Established in North America, but not the Great Lakes**

***Sinelobus standfordi* has a low probability of establishment if introduced to the Great Lakes (Confidence level: Low).**

Sinelobus stanfordi is in Antwerp, which is a major shipping/industrial area, and likely has high population levels there. If individuals found their way into ballast water, ballast exchange would eliminate most individuals from ballast water. Also, traffic from United States water bodies with this species is low to the Great Lakes, so the inoculation via fouling would be low.

First recorded in east equatorial Pacific (Gardiner 1975). *Sinelobus stanfordi* has been collected in Argentina, Brazil, Uruguay, West Indies, Florida (Coral Gables Waterway), Galapagos, Sri Lanka, Sudan, South Africa (Gardiner 1975), Mexico (Hendrickx and Ibarra 2008), British Columbia (Levings and Rafi 1978), Dutch and Belgian North Sea coast, including port of Antwerp (van Haaren and Soors 2009), San Fransisco Bay and delta (Cohen and Carlton 1995); Lower Colombia River and Coos Bay, Oregon (Sytsma et al. 2004, Ruiz et al. 2000), South Carolina (South Carolina Department of Natural Resources 2008), and Washington (Joyce 2005, van Haaren and Soors 2009). Only one study documents the presence of this species specifically as an invasive population (van Haaren and Soors 2009); thus, spread is not known.

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
	8

- Sinelobus stanfordi *tolerates fresh to very saline water, 0-52 ppt (Gardiner 1975).*
- *This species is found in Arcturus Lake (Galapagos), with has very low DO at 10m, nearly no DO at 25m and is exceedingly eutrophic (Gardiner 1975).*
- *In Netherlands* Sinelobus stanfordi *is found in O_2% from 61-102%; found in O_2 as low as 5.8 mg/L (van Haaren and Soors 2009).*

- *This species is found in sediment with temperatures of -2C-23.5C (Levings and Rafi 1978).*

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9
Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
	7

- Sinelobus stanfordi *is found in sediment with temperatures of -2C-23.5C (Levings and Rafi 1978).*
- Sinelobus stanfordi *is found in Arcturus Lake (Galapagos), with has very low DO at 10m, nearly no DO at 25m (Gardiner 1975).*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
	U

- *A paucity of data exists for this species' diet.*

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	0

Unknown	U
	U

- *In Fraser River estuary (British Columbia), densities of 17,400 individuals/0.25m^2 (Levings and Rafi 1978).*

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
	5

- *Female of this species have been observed with 57 eggs (Gardiner 1975).*
- *For family Tanaidacea:*
    - *Mean number of eggs per female of Tanais dulongii was 47.2 (Rumbold et al. 2012).*
    - *Mean number of eggs per female of Monokalliapseudes schubarti was 37 (Freitas-Júnior et al. 2013).*

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
	0

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9

Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	3

- *While the number of purely freshwater populations of this species is low, one location has been in Japan, where the winters are cold and the precipitation is relatively high. Other estuarine populations (e.g., the Netherlands) are known from areas with seasonal weather, including cold winters.*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	U

- *This species is found in freshwater (Gardiner 1975).*
- Sinelobus stanfordi *is found in Arcturus Lake (Galapagos), which is exceedingly eutrophic (Gardiner 1975).*
- *This species is found in sediment with temperatures of -2C-23.5C (Levings and Rafi 1978).*
- *This species is found in Antwerp, which is a major shipping/industrial area and likely has high levels of population (van Haaren and Soors 2009).*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0
Unknown	U
	6

- Sinelobus stanfordi *is a benthic species, found in detritus among mangroves, on fine filamentous algae; constructs tubes on hard or soft bottoms, and on plants (Gardiner 1975).*
- *This species has been found in stony and artificial substrate in the Antwerp harbor; prefers hard substrate (van Haaren and Soors 2009).*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0
Unknown	U
	8

- Sinelobus stanfordi *is tolerant of warmer waters, e.g., collected in Argentina, Brazil, Uruguay, West Indies, Florida (Coral Gables Waterway), Galapagos, Sri Lanka, Sudan, South Africa (Gardiner 1975); Mexico (Hendrickx and Ibarra 2008); British Columbia (Levings and Rafi 1978).*
- *This species is tolerant of a range of salinities.*

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
	U

- *A paucity of data exists for this species' diet.*

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9

Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Great Lakes and is not likely to be introduced	-80% total points (at end)
Unknown	U
	9

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes)	6
Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0
Unknown	U
	U

- *A paucity of data exists for this species.*

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)

Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0
Unknown	U
	-10%

- *As a small benthic species* Sinelobus stanfordi *is likely to be preyed upon. But has established in a variety of locations, so not likely to be impeded by predation.*

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9
Frequent, moderate inocula	6
Frequent, small inocula OR infrequent, large inocula	3
Infrequent, small or moderate inocula	0
Unknown	U
	0

- *Ballast exchange would eliminate most individuals from ballast water. Also, traffic from United States water bodies with this species is low to the Great Lakes, so the inocula via fouling would be low, as well.*

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
	4

- *This species was first recorded in east equatorial Pacific (Gardiner 1975).*
- *This species has been collected in Argentina, Brazil, Uruguay, West Indies, Florida (Coral Gables Waterway), Galapagos, Sri Lanka, Sudan, South Africa (Gardiner 1975); Mexico (Hendrickx and Ibarra 2008); British Columbia (Levings and Rafi 1978); Dutch and Belgian North Sea coast, including port of Antwerp (van Haaren and Soors 2009); San Fransisco Bay and delta (Cohen and Carlton 1995); Lower Colombia River and Coos*

Bay, Oregon (Sytsma et al. 2004, Ruiz et al. 2000), South Carolina (South Carolina Department of Natural Resources 2008) and Washington (Joyce 2005, van Haaren and Soors 2009).

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
	U

- *Only one study documents the presence of this species specifically as an invasive population (van Haaren and Soors 2009); thus, spread is not known.*

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing the establishment and spread of this species)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent the establishment and/or spread of this species	0
Unknown	U
	0

Establishment Potential Scorecard				
Points	**Probability for Establishment**	A. Total Points (pre-adjustment)		50
>100	High	**Adjustments**		
		B. Critical species	A*(1- 0%)	50
51-99	Moderate	C. Natural enemy	B*(1- 0%)	45
		Control measures	C*(1- 0%)	45

0-50	Low	**Potential for Establishment**	Low
# of questions answered as "unable to determine"	**Confidence Level**		
0-1	High	Total # of questions unknown	6
2-5	Moderate		
6-9	Low	Confidence Level	Low
>9	Very low		

Section C: Potential for Impact

<u>IMPACT POTENTIAL RESULTS</u>

Environmental: Low

Socio-Economic: Low

Beneficial: Low

Current research on the potential environmental impacts to result from *Sinelobus stanfordi* if introduced to the Great Lakes is inadequate to support proper assessment.

There is insufficient information available to determine whether *Sinelobus stanfordi* poses a threat to other species or water quality. There are no reports on how it affects or interacts with other species. It is unknown whether this species alters the physical components of the ecosystem.

There is little or no evidence to support that *Sinelobus stanfordi* has the potential for significant socio-economic impacts if introduced to the Great Lakes.

It has not been reported that *Sinelobus stanfordi* poses a threat to human health or water quality. There is no evidence that this species negatively impacts infrastructure, economic sectors, recreational activities and associated tourism, or aesthetic appeals of the areas it inhabits.

There is little or no evidence to support that *Sinelobus stanfordi* has the potential for significant beneficial impacts if introduced to the Great Lakes.
It has not been indicated that *Sinelobus stanfordi* can be used for the control of other organisms or improving water quality. There is no evidence to suggest that this species is commercially, recreationally, or medically valuable. It does not have significant positive ecological impacts.

POTENTIAL ENVIRONMENTAL IMPACT

NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1
Not significantly	0 √
Unknown	U

- *As a small benthic crustacean, this species is not likely to pose a hazard to the health of native species.*

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1
Not significantly	0
Unknown	U √

- *A paucity of data exists for this species.*

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in the food web)	6
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	1
Not significantly	0 √
Unknown	U

- *As a small benthic crustacean, this species is not likely to alter predator-prey relationships.*

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the	1

individual level	
Not significantly	0 √
Unknown	U

- *As a small benthic crustacean, this species is not likely to affect any native populations genetically..*

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1
Not significantly	0 √
Unknown	U

- *As a small benthic crustacean, this species is not likely to negatively affect water quality.*

E6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1
Not significantly	0 √
Unknown	U

- *As a small benthic crustacean, this species is not likely to alter the physical eocsystem.*

Environmental Impact Total	**0**
Total Unknowns (U)	**1**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**Low**
1	0	

<table>
<tr><td>0</td><td>≥2</td><td rowspan="2">Unknown</td></tr>
<tr><td>1</td><td>≥1</td></tr>
</table>

POTENTIAL SOCIO-ECONOMIC IMPACT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1
Not significantly	0 √
Unknown	U

S2) Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1
Not significantly	0 √
Unknown	U

S3) Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0 √
Unknown	U

S4) Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

Socio-Economic Impact Total	**0**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**Low**
1	0	
0	≥2	Unknown
1	≥1	

POTENTIAL BENEFICIAL EFFECT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular effect. An "Unknown" response is appropriate if the potential for a particular effect might be inferred but has not been explicitly reported or if there is an unresolved debate about a particular effect.

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1
Not significantly	0 √
Unknown	U

B2) Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?

Yes, it is economically important to at least one of these industries	6
Yes, but its economic contribution is small	1
Not significantly	0 √
Unknown	U

B3) Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local communities and/or tourism	6
It is sometimes employed recreationally, but adds little value to local communities or tourism	1
Not significantly	0 √
Unknown	U

B4) Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR It is potentially important to medicine or research and is currently being or scheduled to be studied	1
Not significantly	0 √
Unknown	U

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1
Not significantly	0 √

Unknown	U

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1
Not significantly	0 √
Unknown	U

- *There is no evience that* Sinelobus stanfordi *is utilized as a food source for juvenile salmonids at estuarine environments (Levings and Rafi 1978).*

Beneficial Effect Total	**0**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**<u>Low</u>**
1	0	
0	≥2	Unknown
1	≥1	

A.10 Platyhelminthes

Scientific Name: *Leyogonimus polyoon*
Linstow, 1887

Common Name: Trematode Flatworm

Synonyms:

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: Unlikely

Hitchhiking/fouling: Moderate

Unauthorized intentional release: Unlikely

Stocking/planting/escape from recreational culture: Unlikely

Escape from commercial culture: Unlikely

Transoceanic shipping: Unlikely

***Leyogonimus polyoon* has a moderate probability of introduction to the Great Lakes (Confidence level: Moderate).**

Potential pathway(s) of introduction: Hitchhiking/Fouling

Introduction of *L. polyoon* to North America could have resulted from migration of an infected coot from Europe to Canada and then to Wisconsin (Slota et al. 1998). Spread to the Great Lakes could occur via migration of infected birds from Wisconsin or Minnesota to the Great Lakes and subsequent transmission of the parasite to previously uninfected faucet snails. R. Cole (pers. comm.) notes that this parasite likely infects other gallinules, which also would also contribute to its spread potential.

Infected Faucet Snails attached to boats or other equipment could also transport this parasite (Cole and Jankowski 2007).

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100

No, this species does not occur near waters connected to the Great Lakes basin and/or is not mobile or able to be transported by wind or water.	0 √
Unknown	U

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100 √
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0
Unknown	U

- *The parasite* L. polyoon *is dependent on Faucet Snails (*Bithynia tentaculata*) and aquatic insects, such as trichopterans (caddisflies) and odonates (dragonflies and damselflies), as its intermediate hosts and coots as its definitive host (Cole 2001, Cole and Franson 2006, Cole and Jankowski 2007). These species are found in several lakes and rivers in some Great Lakes states, as well as in the Great Lakes themselves.*
- *Introduction of* L. polyoon *to North America could have resulted from migration of an infected coot from Europe to Canada and then to Wisconsin (Slota et al. 1998). Spread to the Great Lakes could occur via migration of infected birds from Wisconsin or Minnesota to the Great Lakes and subsequent transmission of the parasite to previously uninfected faucet snails. R. Cole (pers. comm.) notes that this parasite likely infects other gallinules, which also would also contribute to its spread potential.*
- *Infected Faucet Snails attached to boats or other equipment could also transport this parasite (Cole and Jankowski 2007).*

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5 √
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1
Unknown	U

- Leyogonimus polyoon *is established in several water bodies in the upper mid-western United States, including Lake Winnibigoshish, MN and Lake Butte des Morts, Lake Onalaska, Shewano Lake, and Lake Winneconne, WI (Cole 2001, Cole and Franson 2006, Cole and Jankowski 2007). The geographic range of this species is predicted to be limited to the Great Lakes basin (Cole and Franson 2006).*

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a) Is this species sold at aquarium/pet/garden stores ("brick & mortar" or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100
No, this species this species is rarely/never sold.	0 √
Unknown	U

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0 √
Unknown	U

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is <u>likely</u> to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal	Score x 0.25

or state regulations in more than half the basin (> 5 states/provinces), this activity <u>may</u> occur within 20 km of the basin because of the species' popularity/value.	
Unknown	U

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100
No, this species is not commercially cultured in or transported through the Great Lakes region.	0 √
Unknown	U

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40
No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0
Unknown	U √

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5
Yes, but this species has neither been observed in ballast/fouling ships entering the Great Lakes nor in ports in direct trade with the Great Lakes.	Score x 0.1
No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0 √
Unknown	U

Vector Potential Scorecard				
Vector	**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind	**0**	x	**0**	Unlikely
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.	**100**	x 0.5	**50**	Moderate
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)	**0**	x	**0**	Unlikely
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)	**0**	x	**0**	Unlikely
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)	**0**	x	**0**	Unlikely
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling	**U**	x	**0**	Unlikely
Total Unknowns (U)	**1**	**Confidence Level**	Moderate	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate

1-39	Low
0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

ESTABLISHMENT POTENTIAL RESULTS

Status: **Established in North America, but not the Great Lakes**

***Leyogonimus polyoon* has a moderate probability of establishment if introduced to the Great Lakes (Confidence level: Low).**

In North America, *L. polyoon* is predicted to be geographically restricted to the Great Lakes basin, though it is not yet found below ordinary mean high water or directly connecting waters (Cole and Franson 2006). Establishment in lakes in Minnesota and Wisconsin over the course of a decade suggests that *L. polyoon* could also spread to and overwinter in the Great Lakes, but its environmental parameters are uncharacterized. One of its intermediate hosts, the Faucet Snail, is a non-indigenous aquatic snail from Eurasia that was introduced into Lake Michigan in 1871; this snail has spread to the Great Lakes region, as well as to the mid-Atlantic states and Montana (Invasive Species Program 2011). The trematode's additional required hosts, aquatic insects and American coots, are also widespread in the Great Lakes (Cole 2001). Shallow, protected shorelines where birds feed or rest along the Great Lakes may offer more of an opportunity for *L. polyoon* eggs to hatch from released feces and infect *B. tentaculata* (Cole and Jankowski 2007).

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
	U

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9
Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
	8

- *Establishment in lakes in Minnesota and Wisconsin suggests that* L. polyoon *could also overwinter in the Great Lakes.*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
	3

- Leyogonimus polyoon *parasitizes Faucet Snails and aquatic insect larvae. As an adult, it feeds on blood and tissue of its host coot (Cole 2001, Cole and Franson 2006, Cole and Jankowski 2007).*

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	0
Unknown	U
	U

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
	U

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
	U

- *To complete its complex life history,* L. polyoon *requires snail and larval insect intermediate hosts and one definitive avian (gallinule) host (Cole 2001, Cole and Franson 2006, Cole and Jankowski 2007). All elements are present in the Great Lakes region.*

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0

Unknown	U
	9

- Leyogonimus polyoon *is established in lakes in Minnesota and Wisconsin, where the climate is similar to that of the Great Lakes.*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	9

- Leyogonimus polyoon *is established in lakes in Minnesota and Wisconsin, where the abiotic environment is similar to that of the Great Lakes.*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0
Unknown	U
	9

- *Shallow, protected shorelines where birds feed or rest may offer more of an opportunity for* L. polyoon *eggs to hatch from released feces and infect* B. tentaculata *(Cole and Jankowski 2007).*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Great Lakes a	3

better environment for establishment and spread of this species)	
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0
Unknown	U
	U

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
	9

- *Faucet Snails, aquatic insect larvae, and coots are all present in the Great Lakes.*

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Great Lakes and is not likely to be introduced	-80% total points (at end)
Unknown	U
	9

- *The Faucet Snail,* Bithynia tentaculata*, a non-indigenous aquatic snail from Eurasia, was introduced into Lake Michigan in 1871 and has spread to the mid-Atlantic states, Great Lakes region, Montana, and the Mississippi River basin in Lake Winnibigoshish, MN (Invasive Species Program 2011). Aquatic insects and American Coots are also widespread in the area (Cole 2001).*

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes)	6
Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0
Unknown	U
	8

- *The Faucet Snail serves as an intermediate host for this trematode and is already established in the Great Lakes.*

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0
Unknown	U
	0

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9
Frequent, moderate inocula	6
Frequent, small inocula OR infrequent, large inocula	3
Infrequent, small or moderate inocula	0
Unknown	U
	U

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
	5

- *Before 1996,* L. polyoon*, a parasitic flatworm infecting coots and moorhens, was reported only from Eastern Europe. However, in 1997, large scale mortality of American coots was reported at Shawano Lake, Wisconsin and Lake Winnibigoshish, Minnesota. The parasite has also been found in Lake Butte des Morts and Lake Winneconne, Wisconsin (Cole 2001, Invasive Species Program 2011).*

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0

Unknown	U
	6

- *Bird mortality events initially observed in Shawano Lake, WI spread to four additional water bodies in Wisconsin and Minnesota in the decade following first detection of this parasite (Cole 2001, Cole and Jankowski 2007, Dierauf 2007). It has become a concern that* L. polyoon *could spread to other locations as coots migrate from Shawano Lake and other infected places.*
- *Therefore, it has been considered to control spread of* L. polyoon *by controlling spread of the snail host (Cole 2001). Infected Faucet Snails attached to boats or other equipment could also transport this parasite (Cole and Jankowski 2007).*

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing the establishment and spread of this species)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent the establishment and/or spread of this species	0
Unknown	U
	0

Establishment Potential Scorecard				
Points	**Probability for Establishment**	A. Total Points (pre-adjustment)		75
>100	High	**Adjustments**		
		B. Critical species	A*(1- 0%)	75
51-99	Moderate	C. Natural enemy	B*(1- 0%)	75
		Control measures	C*(1- 0%)	75
0-50	Low	**Potential for Establishment**		Moderate
# of questions answered as "unable to determine"	**Confidence Level**			
0-1	High	Total # of questions unknown		6
2-5	Moderate			

6-9	Low	Confidence Level	Low
>9	Very low		

Section C: Potential for Impact

IMPACT POTENTIAL RESULTS

Environmental: Unknown

Socio-Economic: Unknown

Beneficial: Low

Current research on the potential for environmental impacts to result from *Leyogonimus polyoon* if introduced to the Great Lakes is inadequate to support proper assessment.

Birds infested with *L. polyoon* develop severe enteritis (intestinal trematodiasis), characterized by gross lesions, thickening of intestinal wall, a firm and distended duodenum and jejunum, and fibrinous to caseous cores of necrotic debris in the intestines that occlude the lumen (Cole and Franson 2006). Symptoms are similar to those of avian cholera (Seely 1999), including body weight loss, weakness, lethargy, and death as a result of hemorrhaging, anemia, blood loss, and shock (Cole and Franson 2006, Cole and Jankowski 2007). Heavily infected birds may experience difficulty diving and flying (Cole and Jankowski 2007).

Previous gallinule infestation in the parasite's native range was limited to Eurasian Coot and Common Moorhen, but through its introduction to North America, *L. polyoon* was able to infect the native American coot and likely infects other gallinules (Cole pers. comm., Cole and Franson 2006). Initial dieoffs of over 1,000 American coot in Shewano Lake, located at the headwaters of the Wolf River, WI in 1996 went undiagnosed until a mass mortality event was observed the following fall (Seely 1999). In 1997, infestation of *L. polyoon* killed over 11,000 coot (Cole and Franson 2006, Cole and Friend 1999). By 2002, this parasite had caused the death of more than 24,000 birds in northwestern Wisconsin (Cole 2001). From late October through mid-November 2007, 200 coot on Lake Winnibigoshish in north central Minnesota were killed by fluke infestation, including that by *L. polyoon* (Cole and Jankowski 2007). Population level effects of these mortality events are unknown.

Current research on the potential for socio-economic impacts to result from *Leyogonimus polyoon* if introduced to the Great Lakes is inadequate to support proper assessment.

Mass bird mortality at infested sites may temporarily impact recreational use and diminish the aesthetic value of those areas.

There is little or no evidence to support that *Leyogonimus polyoon* has the potential for significant beneficial effects if introduced to the Great Lakes.

It has not been indicated that *Leyogonimus polyoon* can be used for the control of other organisms or improving water quality. There is no evidence to suggest that this species is commercially, recreationally, or medically valuable. It does not have significant positive ecological impacts.

POTENTIAL ENVIRONMENTAL IMPACT

NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1 √
Not significantly	0
Unknown	U

- *Birds infested with* L. polyoon *develop severe enteritis (intestinal trematodiasis), characterized by gross lesions, thickening of intestinal wall, a firm and distended duodenum and jejunum, and fibrinous to caseous cores of necrotic debris in the intestines that occlude the lumen (Cole and Franson 2006). Symptoms are similar to those of avian cholera (Seely 2009), including body weight loss, weakness, lethargy, and death as a result of hemorrhaging, anemia, blood loss, and shock (Cole and Franson 2006, Cole and Jankowski 2007). Heavily infected birds may experience difficulty diving and flying (Cole and Jankowski 2007).*
- *Initial dieoffs of over 1,000 American Coot in Shewano Lake, located at the headwaters of the Wolf River, WI in 1996 went undiagnosed until a mass mortality event was observed the following fall (Seely 1999). In 1997, infestation of* L. polyoon *killed over 11,000 coot (Cole and Franson 2006, Cole and Friend 1999). By 2002, this parasite had caused the death of more than 24,000 birds in northwestern Wisconsin (Cole 2001). From late October through mid-November 2007, 200 coot on Lake Winnibigoshish in north central Minnesota were killed by fluke infestation, including that by* L. polyoon *(Cole and Jankowski 2007).*

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1
Not significantly	0 √
Unknown	U

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in the food web)	6
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1

AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	
Not significantly	0
Unknown	U √

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0 √
Unknown	U

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1
Not significantly	0 √
Unknown	U

E6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1
Not significantly	0 √
Unknown	U

Environmental Impact Total	**1**
Total Unknowns (U)	**1**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	Low
1	0	
0	≥2	**Unknown**
1	≥1	

POTENTIAL SOCIO-ECONOMIC IMPACT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1
Not significantly	0 √
Unknown	U

S2) Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1
Not significantly	0 √
Unknown	U

S3) Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0 √
Unknown	U

S4) Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6
Yes, but negative consequences have been small	1
Not significantly	0
Unknown	U √

- *Mass bird mortality at infested sites may temporarily impact recreational use of those areas.*

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6
Yes, but negative consequences have been small	1
Not significantly	0
Unknown	U √

- *Mass bird mortality at infested sites may temporarily diminish the aesthetic value of those of those areas.*

Socio-Economic Impact Total	**0**
Total Unknowns (U)	**2**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	Low
1	0	Low
0	≥2	**Unknown**
1	≥1	**Unknown**

POTENTIAL BENEFICIAL EFFECT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular effect. An "Unknown" response is appropriate if the potential for a particular effect might be inferred but has not been explicitly reported or if there is an unresolved debate about a particular effect.

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1
Not significantly	0 √
Unknown	U

B2) Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?

Yes, it is economically important to at least one of these industries	6
Yes, but its economic contribution is small	1
Not significantly	0 √
Unknown	U

B3) Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local communities and/or tourism	6
It is sometimes employed recreationally, but adds little value to local communities or tourism	1
Not significantly	0 √
Unknown	U

B4) Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR It is potentially important to medicine or research and is currently being or scheduled to be studied	1
Not significantly	0 √
Unknown	U

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1
Not significantly	0 √
Unknown	U

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1
Not significantly	0 √
Unknown	U

Beneficial Effect Total	**0**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**Low**
1	0	
0	≥2	Unknown
1	≥1	

A.11 Polychaetes

Scientific Name: *Hypania invalida*
Grube, 1860

Common Name: Freshwater Bristleworm

Synonyms:

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: Unlikely

Hitchhiking/fouling: Unlikely

Unauthorized intentional release: Unlikely

Stocking/planting/escape from recreational culture: Unlikely

Escape from commercial culture: Unlikely

Transoceanic shipping: Moderate

***Hypania invalida* has a moderate probability of introduction to the Great Lakes (Confidence level: High).**

Potential pathway(s) of introduction: Transoceanic Shipping (NOBOB vessels)

This species is present throughout the North Sea basin (lower Rhine) and Baltic Sea basin (Grigorovich et al. 2003), both origins for high volumes of Great Lakes shipping traffic. Ricciardi and Rasmussen (1998) list *H. invalida* as the only Ponto-Caspian polychaete likely to be transported to the Great Lakes via ballast water. Submerged ship pumps have taken in larval specimens without being harmed; these worms then rapidly colonized every flume and bowl attached to the inward flow (Norf et al. 2010). With respect to the Great Lakes, however, Grigorovich et al. (2003) propose this species has a reduced probability of invasion due to the effects of ballast water exchange or flushing. The natural salinity range tolerated by *H. invalida* is 0-12 PSU (Mordukhaĭ-Boltovskoĭ 1964). Therefore, current ballast water regulations (30 ppt flushing) are likely to be effective in reducing the probability of introduction to the Great Lakes. Additionally, Norf et al. (2010) hypothesize that the potential expansion of this species to the Great Lakes is likely to be hindered by ballast water exchange (cf. Gray et al. 2007, Locke et al. 1993).

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100
No, this species does not occur near waters connected to the Great Lakes basin and/or is not mobile or able to be transported by wind or water.	0 √
Unknown	U

- Hypania invalida *is a Ponto-Caspian species that has spread across Europe (Gherardi et al. 2009).*

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0 √
Unknown	U

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a) Is this species sold at aquarium/pet/garden stores ("brick & mortar" or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100

No, this species this species is rarely/never sold.	0 √
Unknown	U

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0 √
Unknown	U

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is likely to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces), this activity may occur within 20 km of the basin because of the species' popularity/value.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100
No, this species is not commercially cultured in or transported through the Great Lakes region.	0 √

Unknown	U

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80 √
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40
No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0
Unknown	U

- *Ricciardi and Rasmussen (1998) list* H. invalida *as the only Ponto-Caspian polychaete likely to be transported to the Great Lakes via ballast water.*
- *Submerged ship pumps have taken in larval specimens without being harmed; these worms then rapidly colonized every flume and bowl attached to the inward flow (Norf et al. 2010).*
- *Grigorovich et al. (2003) propose* H. invalida *has a reduced probability of invasion due to the effects of ballast water exchange or flushing.*
- *The natural salinity range tolerated by* H. invalida *is 0-12 ppt (Mordukhaĭ-Boltovskoĭ 1964). Therefore, current ballast water regulations (30 ppt flushing) are likely to be effective in reducing the probability of introduction to the Great Lakes.*
- *Grigorovich et al. (2003) hypothesized that the potential expansion of this species to the Great Lakes is likely to be hindered by ballast water exchange (cf. Gray et al. 2007, Locke et al. 1993).*

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5 √
Yes, but this species has neither been observed in ballast/fouling ships entering the Great Lakes nor in ports in direct trade with the Great Lakes.	Score x 0.1
No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0
Unknown	U

- *This species is present throughout the North Sea basin (lower Rhine) and Baltic Sea basin (Grigorovich et al. 2003), both origins for high volumes of Great Lakes shipping traffic.*

Vector Potential Scorecard				
Vector	**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind	**0**	x	**0**	Unlikely
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.	**0**	x	**0**	Unlikely
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)	**0**	x	**0**	Unlikely
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)	**0**	x	**0**	Unlikely
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)	**0**	x	**0**	Unlikely
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling	**80**	x 0.5	**40**	Moderate
Total Unknowns (U)	**0**	**Confidence Level**	High	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low

0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

ESTABLISHMENT POTENTIAL RESULTS

Status: **Not established in North America, including the Great Lakes**

***Hypania invalida* has a high probability of establishment if introduced to the Great Lakes (Confidence level: High).**

This species originates in the Ponto-Caspian, a region where climatic conditions are similar to those of the Great Lakes. *Hypania invalida* is able to survive in a wide range of temperature (2-25°C) and salinity (0-12 PSU) (Mordukhaĭ-Boltovskoĭ 1964), both of which are well within the ranges that occur in the Great Lakes. Shorter ice cover duration and warmer water temperatures may also benefit this species by lengthening its suitable yearly spawning period; however, if water becomes too warm, this effect may be detrimental to survival. For instance, in the summer of 2003, when the lower Rhine experienced the highest water temperatures on record (27.8°C max) (Sprokkereef et al. 2008), the population density of *H. invalida* was greatly reduced (Norf et al. 2010). Tolerance to other physiological factors is unknown or unreported, as is information on the mechanisms facilitating overwintering within this species' native range (e.g., lower oxygen tolerance limit).

Hypania invalida prefers areas with soft substrate (e.g., silt, clay, fine sand) and current velocities less than 0.1 m/s (Norf et al. 2010, Zorić et al. 2011). These preferences make most of the Great Lakes basin suitable potential habitat with respect to water motion and bottom composition. Sandy bottoms covered with zebra mussel beds also serve as potential habitat, though settlement densities here are typically lower than those in soft-bottom communities (Norf et al. 2010, Yakovlev and Yakovleva 2010). This species is also able to live at a wide range of water depths (shoreline to 960 m) (Zenkevich 1963).

Hypania invalida is an active filter and deposit feeder, feeding primarily upon diatoms (Gruia and Manoleli 1974). Hence, potential food items will likely not limit the distribution of this species within the Great Lakes.

Hypania invalida has an extensive invasion history throughout Europe (Gherardi et al. 2009), with a spreading pattern that seems to suggest dispersal through a corridor connecting the Danube and Rhine rivers. Its dispersal pattern closely follows that of the European invasive isopod *Jaera istri* (bij de Vaate et al. 2002). Panov et al. (2009) described this species as being at high risk for dispersal and establishment when introduced to a new area. Rapid expansion throughout European inland waterways has been facilitated by both human mediated (ballast water) upstream spread and natural (passive drift) downstream spread (Norf et al. 2010, bij de Vaate et al. 2002). Within a few years of introduction to the Rhine River, it had dispersed along the entire navigable river stretch (Bernauer and Jansen 2006) and into many adjacent waterways, including the Moselle (Devin et al. 2006) and Elbe Rivers (Eggers and Anlauf 2008).

Females have a high net fecundity due to frequent reproductive events (every 2 weeks) throughout maturity; it is estimated that a single female could produce at least 1200 larvae during her lifespan (Norf et al. 2010). Many of the sexual and reproductive traits of *H. invalida* (short generation time, external spermcast fertilization, existence of a dispersive larval phase, etc.) reflect attributes that are postulated to enhance the invasion success of aquatic invertebrates (bij de Vaate et al. 2002, Bossche et al. 2001, Devin and Beisel 2007, Norf et al. 2010, Ricciardi and Rasmussen 1998). The maternal care of offspring (brooding) by this species can additionally increase reproductive success by reducing larval mortality during early planktonic life stages (McHugh 1993, Schroeder and Hermans 1975). Increased knowledge of this species' reproductive characteristics, has led Norf et al. (2010) to highlight the potential of *H. invalida* to invade the Great Lakes (contrary to earlier suggestions that it is unlikely to disperse internationally; cf. Ricciardi and Rasmussen 1998).

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
	6

- Hypania invalida *is able to survive in a wide range of temperature (2-25°C) and salinity (0-12 PSU) (Mordukhaĭ-Boltovskoĭ 1964), both of which are well within the ranges that occur in the Great Lakes.*
- *Tolerance to other physiological factors for this species is unknown or unreported.*

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9
Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
	8

- *Due to the climatic similarities between the Great Lakes and Ponto-Caspian regions (Reid and Orlova 2002) this species most likely endures similar overwintering conditions in its native range.*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
	9

- Hypania invalida *is an active filter and deposit feeder (Gruia and Manoleli 1974), with a non-specific food preference (bij de Vaate et al. 2002).*

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	0
Unknown	U
	3

- *There are currently no reported cases of* H. invalida *outcompeting another species within its invaded range in Europe and no predictions available regarding its potential competitive abilities within the Great Lakes.*

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
	6

- *Females have a high net fecundity due to frequent reproductive events (every 2 weeks) throughout maturity; it is estimated that a single female could produce at least 1200 larvae during her lifespan (Norf et al. 2010).*

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
	9

- *Many of the sexual and reproductive traits of* H. invalida *(short generation time, external spermcast fertilization, etc.) reflect attributes that are postulated to enhance the invasion success of aquatic invertebrates as given by Devin and Beisel (2007) and Ricciardi and Rasmussen (1998) (Norf et al. 2010).*
- *The maternal care of offspring (brooding) by this species can increase reproductive success by reducing larval mortality during early planktonic life stages (McHugh 1993, Schroeder and Hermans 1975).*
- *Increased knowledge of this species' reproductive characteristics, has led Norf et al. (2010) to highlight the potential of* H. invalida *to invade the Great Lakes (contrary to earlier suggestions that it is unlikely to disperse internationally; cf. Ricciardi and Rasmussen 1998).*

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- *The Great Lakes and Ponto-Caspian region are climatically compatible, which is one of the attributing factors to the success of Ponto-Caspian species in the Great Lakes (Reid and Orlova 2002).*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- Hypania invalida *is able to survive in a wide range of temperature (2-25°C) and salinity (0-12 PSU) (Mordukhaĭ-Boltovskoĭ 1964), both of which are well within the ranges that occur in the Great Lakes.*
- Hypania invalida *prefers current velocities less than 0.1 m/s (Norf et al. 2010), making most of the Great Lakes basin suitable habitat with respect to water motion.*
- *Abiotic factors and climatic conditions in the Ponto-Caspian region are quite similar to the Great Lakes, making the region compatible for* H. invalida *(Grigorovich et al. 2003, Reid and Orlova 2002).*
- *Great Lakes underwent similar anthropogenic eutrophication as the Ponto-Caspian region (Reid and Orlova 2002). Surface water temperature is similar between the Great Lakes and Ponto-Caspian seas (Grigorovich et al. 2003, Reid and Orlova 2002, USEPA 2008).*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0
Unknown	U
	7

- *This species is restricted to soft-bottom communities (e.g., silt, clay, fine sand) (Zorić et al. 2011).*
- *Sandy bottoms covered with zebra mussel beds also serve as potential habitat, though settlement densities here are typically lower than those in soft-bottom communities (Norf et al. 2010, Yakovlev and Yakovleva 2010).*
- Hypania invalida *is able to live at a wide range of water depths (shoreline to 960 m) (Zenkevich 1963).*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and	0

spread of this species or would make the environment of the Great Lakes unsuitable)	
Unknown	U
	8

- *Increased salinization as a predicted effect of climate change may give this species a competitive advantage over Great Lakes native polychaetes.*
- *Shorter ice cover duration and warmer water temperatures may also benefit this species by lengthening its suitable yearly spawning period; however, if water becomes too warm, this effect may be detrimental to survival. For instance, in the summer of 2003, the lower Rhine experienced the highest water temperatures on record, greatly reducing the population density of H. invalida (Norf et al. 2010).*

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
	9

- Hypania invalida *is an active filter and deposit feeder, feeding primarily upon diatoms (Gruia and Manoleli 1974). Hence, potential food items will likely not limit the distribution of this species within the Great Lakes.*

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in	-80% total

the Great Lakes and is not likely to be introduced	points (at end)
Unknown	U
	9

- *There is no critical species required by* H. invalida.

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes)	6
Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0
Unknown	U
	0

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0
Unknown	U
	0

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9
Frequent, moderate inocula	6
Frequent, small inocula OR infrequent, large inocula	3
Infrequent, small or moderate inocula	0
Unknown	U
	U

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
	6

- Hypania invalida *has an extensive invasion history throughout Europe (Gherardi et al. 2009), with a spreading pattern that seems to suggest dispersal through a corridor connecting the Danube and Rhine rivers.*
- *Its dispersal pattern closely follows that of the European invasive isopod* Jaera istri *(bij de Vaate et al. 2002).*
- *Panov et al. (2009) described this species as being at high risk for dispersal and establishment when introduced to a new area.*

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0

Unknown	U
	6

- *Rapid expansion throughout European inland waterways has been facilitated by both human mediated (ballast water) upstream spread and natural (passive drift) downstream spread (bij de Vaate et al. 2002, Norf et al. 2010).*
- *Within a few years of introduction to the Rhine River, it had dispersed along the entire navigable river stretch (Bernauer and Jansen 2006) and into many adjacent waterways, including the Moselle (Devin et al. 2006) and Elbe rivers (Eggers and Anlauf 2008).*

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing the establishment and spread of this species)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent the establishment and/or spread of this species	0
Unknown	U
	0

Establishment Potential Scorecard				
Points	**Probability for Establishment**	A. Total Points (pre-adjustment)		102
>100	High	**Adjustments**		
		B. Critical species	A*(1- 0%)	102
51-99	Moderate	C. Natural enemy	B*(1- 0%)	102
		Control measures	C*(1- 0%)	102
0-50	Low	**Potential for Establishment**		High
# of questions answered as "unable to determine"	**Confidence Level**			
0-1	High	Total # of questions unknown		1
2-5	Moderate			

6-9	Low	Confidence Level	High
>9	Very low		

Section C: Potential for Impact

IMPACT POTENTIAL RESULTS

Environmental: Low

Socio-Economic: Low

Beneficial: Low

There is little or no evidence to support that *Hypania invalida* has the potential for significant environmental impacts if introduced to the Great Lakes.

Panov et al. (2009) list *H. invalida* as a white-list species, meaning there is a low risk of it causing significant ecological impacts to introduced areas. There are currently no reports of significant environmental impacts attributed to the presence of this species. Zorić et al. (2011) conclude that this species has limited influence on the overall benthic community.

There is little or no evidence to support that *Hypania invalida* has the potential for significant socio-economic impacts if introduced to the Great Lakes.

Panov et al. (2009) list *H. invalida* as a white-list species, meaning there is a low risk of it causing significant socio-economic impacts within introduced areas. There are currently no reports of significant socio-economic attributed to the presence of this species.

There is little or no evidence to support that *Hypania invalida* has the potential for significant beneficial effects if introduced to the Great Lakes.

Hypania invalida was intentionally introduced to areas of the Volga River in the 1950s-1960s to enhance the nutrition base for tank-raised fish (Dzyuban and Slobodchikov 1980, Nechvalenko 1977).

POTENTIAL ENVIRONMENTAL IMPACT

NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6

Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1
Not significantly	0 √
Unknown	U

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1
Not significantly	0 √
Unknown	U

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in the food web)	6
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	1
Not significantly	0 √
Unknown	U

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0 √
Unknown	U

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR	6

Yes, and it has resulted in significant negative consequences for at least one native species	
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1
Not significantly	0 √
Unknown	U

E6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1
Not significantly	0 √
Unknown	U

Environmental Impact Total	**0**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**<u>Low</u>**
1	0	
0	≥2	Unknown
1	≥1	

<u>POTENTIAL SOCIO-ECONOMIC IMPACT</u>

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1
Not significantly	0 √
Unknown	U

S2) Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1
Not significantly	0 √
Unknown	U

S3) Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0 √
Unknown	U

S4) Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly	6

diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

Socio-Economic Impact Total	**0**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**<u>Low</u>**
1	0	
0	≥2	Unknown
1	≥1	

<u>POTENTIAL BENEFICIAL EFFECT</u>

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular effect. An "Unknown" response is appropriate if the potential for a particular effect might be inferred but has not been explicitly reported or if there is an unresolved debate about a particular effect.

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1
Not significantly	0 √
Unknown	U

B2) Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?

Yes, it is economically important to at least one of these industries	6
Yes, but its economic contribution is small	1 √
Not significantly	0
Unknown	U

- Hypania invalida *was intentionally introduced to areas of the Volga River in the 1950s-1960s to enhance the nutrition base for tank-raised fish (Dzyuban and Slobodchikov 1980, Nechvalenko 1977).*

B3) Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local communities and/or tourism	6
It is sometimes employed recreationally, but adds little value to local communities or tourism	1
Not significantly	0 √
Unknown	U

B4) Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR It is potentially important to medicine or research and is currently being or scheduled to be studied	1
Not significantly	0 √
Unknown	U

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1
Not significantly	0 √
Unknown	U

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1
Not significantly	0 √
Unknown	U

Beneficial Effect Total	**1**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**Low**
1	0	
0	≥2	Unknown
1	≥1	

A.12 Rotifers

Scientific Name: *Brachionus leydigii*
Cohn, 1862

Common Name: Wheel Animal

Synonyms:

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: Unlikely

Hitchhiking/fouling: Unlikely

Unauthorized intentional release: Unlikely

Stocking/planting/escape from recreational culture: Unlikely

Escape from commercial culture: Unlikely

Transoceanic shipping: High

***Brachionus leydigii* has a high probability of introduction to the Great Lakes (Confidence level: High).**

Potential pathway(s) of introduction: Transoceanic Shipping

Brachionus ledygii has been identified as having high probability of introduction to the Great Lakes via residual ballast sediment, where its resting stage is able to survive high salinities during ballast water exchange (Bailey et al. 2004, Bailey et al. 2005a, Bailey et al. 2005b; Johengen et al. 2005). In a survey of the ballast water of 35 different vessels entering the Great Lakes, this species was found hatched from diapausing eggs in residual ballast sediment in four of the ships. Additionally, it was isolated from the sediment of those ships with a mean density of 3 individuals/40 g sediment (Bailey et al. 2005a, Johengen et al. 2005). It is likely that these resting stages are deposited by reproducing females taken in with ballast water rather than being brought in with disturbed sediments. Diapausing eggs present in sediment can pose an invasion risk if they are discharged during ballast operations or if they hatch during a voyage and the young rotifers are subsequently introduced during vessel deballasting (Gray and MacIsaac 2010). Of the 76 distinct taxa with a resting stage identified in this survey, *Brachionus* spp. were the most common and abundant of the Great Lakes non-natives (Bailey et al. 2005). *Brachionus* spp. are a predominant component of the planktonic community in the lower Rhine River, a region where ballast is commonly taken for ships entering the Great Lakes (van Dijk and van Zanten 2005). However, this primarily freshwater species is less abundant in other ballast loading regions such as the Baltic Sea and coastal areas with high salinity (Viitasalo et al. 1995).

In more recent studies conducted since the 2006 (Canadian bound vessels) and 2008 (United States bound vessels) expansion of mandatory ballast flushing regulations to vessels with unpumpable ballast tank residuals, however, *B. leydigii* has been identified as having a significantly lower probability of introduction (Briski et al. 2010, Government of Canada 2006, Gray and MacIsaac 2010). *Brachionus leydigii* was not observed in ballast sediment collected in 2007 and 2008 from 19 ballast tanks of 17 randomly selected Great Lakes bound ships originating from European, South American, and Atlantic ports (i.e. after the new regulations were in place) (Briski et al. 2010). Furthermore, in situ hatching studies suggest that fewer than 1% of diapausing invertebrate eggs will hatch and become available for introduction. The likelihood of this species entering the Great Lakes is therefore reduced as compared to species that may become resuspended in ballast water (Johengen et al. 2005). Additionally, Santagata et al. (2008) report a 100% mortality rate for rotifers exposed to full strength seawater for one hour in both empty-refill and flow-through treatments.

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100
No, this species does not occur near waters connected to the Great Lakes basin and/or is not mobile or able to be transported by wind or water.	0 √
Unknown	U

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0 √

Unknown	U

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1
Unknown	U

<u>POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE</u>

3a) Is this species sold at aquarium/pet/garden stores ("brick & mortar" or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100
No, this species this species is rarely/never sold.	0 √
Unknown	U

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1
Unknown	U

<u>POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE</u>

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0 √
Unknown	U

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1

This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is likely to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces), this activity may occur within 20 km of the basin because of the species' popularity/value.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100
No, this species is not commercially cultured in or transported through the Great Lakes region.	0 √
Unknown	U

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80 √
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains,	40

chain locker) while in its active or resting stage.	
No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0
Unknown	U

- *In a survey of the ballast water of 35 different vessels entering the Great Lakes, this species was found hatched from diapausing eggs in residual ballast sediment in four of the ships. Additionally, it was isolated from the sediment of those ships, with a mean density of 3 individuals/40 g sediment. It is likely that these resting stages are deposited by reproducing females taken in with ballast water rather than being brought in with disturbed sediments. Of the 76 distinct taxa with a resting stage identified in this particular survey,* Brachionus *spp. were the most common and abundant of the Great Lakes non-natives (Bailey et al. 2005a, Johengen et al. 2005).*
- *In more recent studies conducted since the 2006 (Canadian bound vessels) and 2008 (United States bound vessels) expansion of mandatory ballast flushing regulations to vessels with unpumpable ballast tank residuals, however,* B. leydigii *has been identified as having a significantly lower probability of introduction (Briski et al. 2010, Government of Canada 2006, Gray and MacIsaac 2010).* Brachionus leydigii *was not observed in ballast sediment collected in 2007 and 2008 from 19 ballast tanks of 17 randomly selected Great Lakes bound ships originating from European, South American, and Atlantic ports (i.e. after the new regulations were in place) (Briski et al. 2010).*
- *Santagata et al. (2008) report a 100% mortality rate for rotifers exposed to full strength seawater for one hour in both empty-refill and flow-through treatments.*
- *In situ hatching studies suggest that fewer than 1% of diapausing invertebrate eggs will hatch and be available for introduction. The likelihood of this species entering the Great Lakes is therefore reduced as compared to species that are able to suspend in ballast water (Johengen et al. 2005).*
- *Johengen et al. (2005) report observing one* B. leydigii *individual in an upper-wing ballast tank of a surveyed vessel, leading the authors to suggest that this may have been the result of a previous transoceanic ballast introduction to Hamilton Harbor, as residual sediments generally do not accumulate in upper-wing tanks. Because only a single individual was recorded, the status of establishment cannot be determined, but this finding may be an indication that* B. leydigii *has been introduced previously to this location (Johengen et al. 2005).*

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1 √
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5
Yes, but this species has neither been observed in ballast/fouling ships entering the Great Lakes nor in ports in direct trade with the Great Lakes.	Score x 0.1
No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0
Unknown	U

- Brachionus *spp. are a predominant component of the planktonic community in the lower Rhine River, a region where ballast is commonly taken for ships entering the Great Lakes (van Dijk and van Zanten 2005). However, this primarily freshwater species is less abundant in other ballast loading regions such as the Baltic Sea and coastal areas with high salinity (Viitasalo et al. 1995).*
- *In a survey of the ballast water of 35 different vessels entering the Great Lakes, this species was found hatched from diapausing eggs in residual ballast sediment in four of the ships. Additionally, it was isolated from the sediment of those ships, with a mean density of 3 individuals/40 g sediment. It is likely that these resting stages are deposited by reproducing females taken in with ballast water rather than being brought in with disturbed sediments. Of the 76 distinct taxa with a resting stage identified in this particular survey,* Brachionus *spp. were the most common and abundant of the Great Lakes non-natives (Bailey et al. 2005a, Johengen et al. 2005).*

- *Johengen et al. (2005) report observing one* B. leydigii *individual in an upper-wing ballast tank of a surveyed vessel, leading the authors to suggest that this may have been the result of a previous transoceanic ballast introduction to Hamilton Harbor, as residual sediments generally do not accumulate in upper-wing tanks. Because only a single individual was recorded, the status of establishment cannot be determined, but this finding may be an indication that* B. leydigii *has been introduced previously to this location (Johengen et al. 2005).*

Vector Potential Scorecard					
Vector		**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind		**0**	x	**0**	Unlikely
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.		**0**	x	**0**	Unlikely
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)		**0**	x	**0**	Unlikely
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)		**0**	x	**0**	Unlikely
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)		**0**	x	**0**	Unlikely
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling		**80**	x 1	**80**	High
Total Unknowns (U)	**0**	**Confidence Level**		High	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

ESTABLISHMENT POTENTIAL RESULTS

Status: **Not established in North America, including the Great Lakes**

Brachionus leydigii **has a moderate probability of establishment if introduced to the Great Lakes (Confidence level: Moderate).**

This species produces a resting stage consisting of a three-layered diapausing egg that is protected from external stressors, such as desiccation and temperature extremes, until conditions become favorable and a viable individual hatches (Clement and Wurdak 1991, Sladecek 1983, Wurdak et al. 1978). This reproductive strategy leads *B. ledygii* to having high Great Lakes invasion potential, as diapausing eggs can be resistant to short term salinity exposure, are not easily flushed from ballast tanks, and have the potential for in situ hatching during a transoceanic voyage (Bailey et al. 2003, Bailey et al. 2004, Bailey et al. 2005a, Bailey et al. 2005b, Bailey et al. 2006, Gray et al. 2005, Gray and MacIsaac 2010). However, viability of similarly resistant diapausing copepods and cladoceran eggs is low under conditions of low oxygen or anoxia (Carvalho and Wolf 1989, Uye 1980, Uye et al. 1984).

Branchionus leydigii is distributed globally and present in a variety of physical and environmental conditions. Bailey et al. (2005a) and Johengen et al. (2005) reported this species as a having a habitat match to the Great Lakes, able to hatch in a 0 ppt salinity medium. Additionally, because *B. leydigii* thrives in primarily eutrophic conditions, the central and western basins of Lake Erie may provide potential suitable habitat due to their high eutrophication potential (Summers 2001). Johengen et al. (2005) report observing one *B. leydigii* individual in an upper-wing ballast tank of a surveyed vessel, leading the authors to suggest that this may have been the result of a previous transoceanic ballast introduction to Hamilton Harbor, as residual sediments generally do not accumulate in upper-wing tanks. Because only a single individual was recorded, the status of establishment cannot be determined, but this finding may indicate that *B. leydigii* has been introduced previously to this location (Johengen et al. 2005).

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
	6

- Brachionus ledygii *is distributed globally and present in a variety of physical and environmental conditions. Bailey et al. (2005) and Johengen et al. (2005) reported this species as a having habitat match to the Great Lakes, able to hatch in a 0 ppt salinity medium.*

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9
Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
	6

- *This species produces a resting stage consisting of a three-layered diapausing egg that is protected from external stressors, such as desiccation and temperature extremes (Clement and Wurdak 1991, Sladecek 1983, Wurdak et al. 1978). However, viability of similarly resistant diapausing copepods and cladoceran eggs is low under conditions of low oxygen or anoxia (Carvalho and Wolf 1989, Uye 1980, Uye et al. 1984).*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
	6

- Brachionus ledygii *filter feeds on small material such as bacteria and detritus and is able to selectively filter particles by size with a corona of cilia surrounding its mouth (Wallace 2002).*

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3

Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	0
Unknown	U
	3

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
	U

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
	U

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes	3

region)	
Not similar	0
Unknown	U
	8

- *This species exists in a worldwide distribution, with many localities having climatic conditions similar to those of the Great Lakes (i.e. Ponto-Caspian region including the Rhine River) (van Dijk and van Zanten 2005).*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- *Bailey et al. (2005a) classifies this species as having a habitat match to the Great Lakes based upon its ability to hatch in a 0 ppt medium.*
- *Abiotic factors and climatic conditions in the Ponto-Caspian region are quite similar to the Great Lakes, making the region compatible for this species (Grigorovich et al. 2003, Reid and Orlova 2002).*
- *Great Lakes underwent similar anthropogenic eutrophication as the Ponto-Caspian region (Reid and Orlova 2002). Surface water temperature is similar between the Great Lakes and Ponto-Caspian seas (Grigorovich et al. 2003, Reid and Orlova 2002, USEPA 2008).*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0
Unknown	U
	9

- Brachionus leydigii *thrives primarily in eutrophic environments (Maemets 1983, Sladecek 1983), likely making the central and western basins of Lake Erie the most suitable potential habitat due to their high eutrophication potential (Summers 2001).*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0
Unknown	U
	U

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
	9

- *This species is a filter feeder, feeding primarily on bacteria, small algae, and detritus (Wallace 2002), all of which are non-limiting resources in the Great Lakes.*

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6

Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Great Lakes and is not likely to be introduced	-80% total points (at end)
Unknown	U
	9

- *There is no critical species required for the survival of* B. leydigii.

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes)	6
Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0
Unknown	U
	U

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)

Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0
Unknown	U
	0

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9
Frequent, moderate inocula	6
Frequent, small inocula OR infrequent, large inocula	3
Infrequent, small or moderate inocula	0
Unknown	U
	3

- *Of 23 Great Lakes nonindigenous species observed in ballast sediment, this species occurred in the greatest number of sampled ships (4/35) and had a relatively large abundance (3 individuals/40 g sediment) (Bailey et al. 2005a).*
- *In situ hatching studies suggest that less than 1% of diapausing invertebrate eggs will hatch and be available for introduction, thus reducing propagule pressure (Johengen et al. 2005).*

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
	0

- *This species has a broad global distribution with no specific records of nonindigenous occurrences.*

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
	U

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing the establishment and spread of this species)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent the establishment and/or spread of this species	0
Unknown	U
	0

Establishment Potential Scorecard				
Points	**Probability for Establishment**	A. Total Points (pre-adjustment)		67
>100	High	**Adjustments**		
		B. Critical species	A*(1- 0%)	67
51-99	Moderate	C. Natural enemy	B*(1- 0%)	67
		Control measures	C*(1- 0%)	67
0-50	Low	**Potential for Establishment**		Moderate
# of questions answered as “unable to determine”	**Confidence Level**			
0-1	High	Total # of questions unknown		5
2-5	Moderate			

6-9	Low	Confidence Level	Moderate
>9	Very low		

Section C: Potential for Impact

POTENTIAL IMPACT RESULTS

Environmental: Low

Socio-Economic: Low

Beneficial: Low

There is little or no evidence to support that *Brachionus leydigii* has the potential for significant environmental impacts if introduced to the Great Lakes.

While rotifers tend to be significant contributors to food web structure due to high abundances and rapid turnover rates, there is no species specific information currently available on the trophic effect of introduced populations of *B. ledygii*. In addition, approximately 275 species of rotifers have already been reported in the Great Lakes, and it is unlikely that the addition of a single species will lead to any new significant environmental impacts.

There is little or no evidence to support that *Brachionus leydigii* has the potential for significant socio-economic impacts if introduced to the Great Lakes.

As a group, introduced rotifers are not known to generate significant socio-economic impacts (O'Connor et al. 2008), and there are currently no reports of this species leading to negative impact in introduced areas.

There is little or no evidence to support that *Brachionus leydigii* has the potential for significant beneficial effects if introduced to the Great Lakes.

Rotifers have been widely used as a bioindicator species in pollution monitoring, and due to their sensitivity to pollutants and ease of culture, they have become important tools in ecotoxicological testing (Wallace 2002). However, there is no evidence supporting that *B. leydigii* will offer any advantage as an ecological indicator as compared to rotifers already present in the Great Lakes.

POTENTIAL ENVIRONMENTAL IMPACT

NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1
Not significantly	0 √
Unknown	U

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1
Not significantly	0 √
Unknown	U

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in the food web)	6
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	1
Not significantly	0 √
Unknown	U

- *While rotifers tend to be significant contributors to food web structure due to high abundances and rapid turnover rates, there is no species specific information currently available on the trophic effect of introduced populations of* B. ledygii. *In addition, approximately 275 species of rotifers have already been reported in the Great Lakes, and it is unlikely that the addition of a single species will lead to any new significant environmental impacts.*

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0 √

Unknown	U

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1
Not significantly	0 √
Unknown	U

E6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1
Not significantly	0 √
Unknown	U

Environmental Impact Total	**0**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**Low**
1	0	
0	≥2	Unknown
1	≥1	

POTENTIAL SOCIO-ECONOMIC IMPACT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1
Not significantly	0 √
Unknown	U

S2) Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1
Not significantly	0 √
Unknown	U

S3) Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0 √
Unknown	U

S4) Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6

Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

Socio-Economic Impact Total	**0**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**Low**
1	0	
0	≥2	Unknown
1	≥1	

POTENTIAL BENEFICIAL EFFECT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular effect. An "Unknown" response is appropriate if the potential for a particular effect might be inferred but has not been explicitly reported or if there is an unresolved debate about a particular effect.

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1
Not significantly	0 √
Unknown	U

B2) Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?

Yes, it is economically important to at least one of these industries	6
Yes, but its economic contribution is small	1
Not significantly	0 √
Unknown	U

B3) Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local communities and/or tourism	6
It is sometimes employed recreationally, but adds little value to local communities or tourism	1
Not significantly	0 √
Unknown	U

B4) Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR It is potentially important to medicine or research and is currently being or scheduled to be studied	1
Not significantly	0 √
Unknown	U

- *Rotifers have been widely used as a bioindicator species in pollution monitoring, and due to their sensitivity to pollutants and ease of culture, they have become important tools in ecotoxicological testing (Wallace 2002). However, there is no evidence supporting that* B. leydigii *will offer any advantage as an ecological indicator as compared to rotifers already present in the Great Lakes.*

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1
Not significantly	0 √
Unknown	U

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1
Not significantly	0 √
Unknown	U

Beneficial Effect Total	**0**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**Low**
1	0	
0	≥2	Unknown
1	≥1	

Scientific Name: *Filinia cornuta*
Weisse, 1847

Common Name:

Synonyms:

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: Unlikely

Hitchhiking/fouling: Unlikely

Unauthorized intentional release: Unlikely

Stocking/planting/escape from recreational culture: Unlikely

Escape from commercial culture: Unlikely

Transoceanic shipping: High

***Filinia cornuta* has a high probability of introduction to the Great Lakes (Confidence level: High).**

Potential pathway(s) of introduction: Transoceanic Shipping

Rotifer identified as having high probability of invasion if introduced to the Great Lakes. Potential pathway of introduction: ballast sediment. Resting stage may survive transport under harsh conditions such as in ballast tanks and ballast sediment (Bailey et al. 2005, Johengen et al. 2005). NOTE: This species is identified as having lower probability of invasion due to the effects of ballast water exchange or flushing (Briski et al. 2010).

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100
No, this species does not occur near waters connected to the Great Lakes basin and/or is not mobile or able to be transported by wind or water.	0 √
Unknown	U

- Filinia cornuta *is widely distributed around the world, but it is not known from North America.*

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0 √
Unknown	U

- Filinia cornuta *is widely distributed around the world (including Hungary, Austria, Turkey, Mexico, China, Israel, Russia, and Brazil), but it is not known from North America.*

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a) Is this species sold at aquarium/pet/garden stores ("brick & mortar" or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100
No, this species this species is rarely/never sold.	0 √
Unknown	U

- Filinia cornuta *is never sold or used in market. It has been relatively well documented since 1983 and there is no record of its importance as a biological supply or educational tool.*
- *However, in Israel, this species has been used as food for fish larvae (e.g., carp larvae) (Valdenberg et al. 2006).*

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0 √
Unknown	U

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is likely to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces), this activity may occur within 20 km of the basin because of the species' popularity/value.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100
No, this species is not commercially cultured in or transported through the Great Lakes region.	0 √
Unknown	U

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80 √
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40
No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0
Unknown	U

- Filinia cornuta *was one of 76 taxa documented following analysis of residual sediments from 36 ships entering the Great Lakes (Briski et al. 2010). The occurrence of these resting eggs was reduced from a mean of 3 resting eggs per 40 g sediment to zero after flushing ballast tanks with salt water, per current regulations (Briski et al. 2010).*

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1 √
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5
Yes, but this species has neither been observed in ballast/fouling ships entering the Great Lakes nor in ports in direct trade with the Great Lakes.	Score x 0.1
No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0
Unknown	U

- Filinia cornuta *was one of 76 taxa documented following analysis of residual sediments from 36 ships entering the Great Lakes (Briski et al. 2010). The occurrence of these resting eggs was reduced from a mean of 3 resting eggs per 40 g sediment to zero after flushing ballast tanks with salt water, per current regulations (Briski et al. 2010).*

Vector Potential Scorecard					
Vector		**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind		**0**	x	**0**	Unlikely
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.		**0**	x	**0**	Unlikely
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)		**0**	x	**0**	Unlikely
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)		**0**	x	**0**	Unlikely
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)		**0**	x	**0**	Unlikely
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling		**80**	x 1	**80**	High
Total Unknowns (U)	**0**	**Confidence Level**		High	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

ESTABLISHMENT POTENTIAL RESULTS

Status: Not established in North America, including the Great Lakes

***Filinia cornuta* has a moderate probability of establishment if introduced to the Great Lakes (Confidence level: moderate).**

This species is identified as having high probability of invasion if introduced to the Great Lakes. Potential pathway of introduction is ballast sediment. Resting stage of this species may survive transport under harsh conditions such as in ballast tanks and ballast sediment (Bailey et al. 2005, Johengen et al. 2005). NOTE: This species is identified as having lower probability of invasion due to the effects of ballast water exchange or flushing (Briski et al. 2010).

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
	6

- Filinia cornuta *has been found in the saline-alkaline Lake Dalu in China with temperatures at 23-24°C (Zhao et al. 2002).*
- *In experiments conducted on eutrophic Huetzalin Lake in Mexico,* F. cornuta *was found in samples where temperatures ranged from 14-24°C, DO ranged from 1.36-13.6 mg/L (García et al. 2009).*
- *This species is also found in Asartepe Dam Lake, Turkey, which froze over the winter (Buyurgan et al. 2010).*

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9
Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
	5

- *In experiments conducted on eutrophic Huetzalin Lake in Mexico,* F. cornuta *was found in samples where DO ranged from 1.36-13.6 mg/L (García et al. 2009).*
- *This species is also found in Asartepe Dam Lake, Turkey, which froze over the winter (Buyurgan et al. 2010).*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
	6

- Filinia cornuta *is a heterotrophic species that feeds on small algae (Sladecek 1983).*

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	0
Unknown	U
	U

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
	U

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
	U

- *The reproductive strategy for this species has not been recorded.*

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- Filinia cornuta *is widely distributed and has been found in Ankara, Turkey in Asartepe Dam Lake (Buyurgan, et al. 2010). This lake freezes in the winter, but has summer temperatures of 23.5°C.*
- *This species has also been found in a Hungarian lake (Schöll and Kiss et al. 2009). The climate in Hungary is similar to the Great Lakes (average air temperature summer high of 73-82°F and winter low of 19-27°F).*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3

Not similar	0
Unknown	U
	7

- Filinia cornuta *has been found in the saline-alkaline Lake Dalu in China with temperatures at 23-24°C (Zhao et al. 2002).*
- *In experiments conducted on eutrophic Huetzalin Lake in Mexico,* F. cornuta *was found in samples where temperatures ranged from 14-24°C, DO ranged from 1.36-13.6 mg/L (García et al. 2009).*
- Filinia cornuta *is widely distributed and has been found in Ankara, Turkey in Asartepe Dam Lake (Buyurgan, et al. 2010). This lake freezes in the winter, but has summer temperatures of 23.5°C.*
- *This species has also been found in a Hungarian lake (Schöll and Kiss 2009). The climate in Hungary is similar to the Great Lakes (average air temperature summer high of 73-82°F and winter low of 19-27°F).*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0
Unknown	U
	7

- Filinia cornuta *has been found in a floodplain with dense macrovegetation in Hungary (Schöll and Kiss 2009).*
- *In Mexico, this species was found in a shallow lake with average depth less than 3m (García et al. 2009).*
- *Given the range of DO and temperatures tolerated by this species, it should be able to find suitable habitat in the Great Lakes basin.*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0
Unknown	U
	5

- Filinia cornuta *has been found in the saline-alkaline Lake Dalu in China with temperatures at 23-24°C (Zhao et al. 2002).*

- *In experiments conducted on eutrophic Huetzalin Lake in Mexico,* F. cornuta *was found in samples where temperatures ranged from 14-24°C, DO ranged from 1.36-13.6 mg/L (García et al. 2009).*

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
	5

- *A number of algal species are present in the Great Lakes, making it likely that* Filinia cornuta *could feed on species available in these waters.*

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Great Lakes and is not likely to be introduced	-80% total points (at end)
Unknown	U
	9

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes)	6
Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0
Unknown	U
	0

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0
Unknown	U
	0

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9
Frequent, moderate inocula	6
Frequent, small inocula OR infrequent, large inocula	3

Infrequent, small or moderate inocula	0
Unknown	U
	U

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
	7

- *This species has been reported from lakes in Europe, China, and Mexico (García et al. 2009, Schöll and Kiss 2009, Zhao et al. 2002)*

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
	U

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing the establishment and spread of this species)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used	-50% total points (at

to control its establishment and spread)	end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent the establishment and/or spread of this species	0
Unknown	U
	0

Establishment Potential Scorecard				
Points	**Probability for Establishment**	A. Total Points (pre-adjustment)		65
>100	High	**Adjustments**		
		B. Critical species	A*(1- 0%)	65
51-99	Moderate	C. Natural enemy	B*(1- 0%)	65
		Control measures	C*(1- 0%)	65
0-50	Low	**Potential for Establishment**		Moderate
# of questions answered as "unable to determine"	**Confidence Level**			
0-1	High	Total # of questions unknown		5
2-5	Moderate			
6-9	Low	Confidence Level		Moderate
>9	Very low			

Section C: Potential for Impact

IMPACT POTENTIAL RESULTS

Environmental: Unknown

Socio-Economic: Low

Beneficial: Low

Current research on the potential for socioeconomic impacts to result from *Filinia cornuta* if introduced to the Great Lakes is inadequate to support proper assessment.

Filinia cornuta is not known to harm any economic sectors and there is no record of this species posing a threat to human health, and the species is not known to negatively affect water quality. Rotifers in general are indicators for organic pollution (Sladecek 1983).

There is little or no evidence to support that *Filinia cornuta* has the potential for significant environmental impacts if introduced to the Great Lakes.

Filinia cornuta is a widely distributed animal across the world. There is no report of this species posing threat to native species in over more than 25 years of records (Sledecek 1983).

***Filinia cornuta* has the potential for moderate beneficial effects if introduced to the Great Lakes.**

This species is important as a food source for fishes (Geng et al. 2005), including for fish larvae (e.g., carp larvae) (Swift 1992, Valdenberg et al 2006). Colloids (suspended solids) and wastewater provide common food sources for this species and it may enhance water quality (Sladecek 1983).

POTENTIAL ENVIRONMENTAL IMPACT

NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1
Not significantly	0 √
Unknown	U

- Filinia cornuta *is a widely distributed animal across the world. It has been found in Turkey, Russia, Brazil, Mexico, Austria, Hungary, New Zealand, and China. There is no report of it posing threat to native species over more than 25 years of records (Sledecek 1983).*

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1
Not significantly	0 √
Unknown	U

- Filinia cornuta *is a heterotrophic species that feeds mainly on algae.*

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in the food web)	6
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	1
Not significantly	0 √
Unknown	U

- Filinia cornuta *feeds mainly on algae smaller than 10 µm. The Great Lakes contain at least 24 kinds of algae (Mills et al. 1993).*
- *This species is important as a food sources for fishes (Geng et al. 2005), including for fish larvae (e.g., carp larvae) (Valdenberg et al. 2006).*

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0
Unknown	U √

- *No information on the potential for genetic effects by this species was found.*

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1
Not significantly	0
Unknown	U √

- *This species is not known to negatively affect water quality; however, it feeds on the colloids that are suspended in the water. Therefore, it might enhance the water quality instead (Sladecek 1983).*

E6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1
Not significantly	0
Unknown	U √

Environmental Impact Total	**0**
Total Unknowns (U)	**3**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	Low
1	0	
0	≥2	**Unknown**
1	≥1	

POTENTIAL SOCIO-ECONOMIC IMPACT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1
Not significantly	0 √
Unknown	U

- *There is no record of this species posing a threat to human health, but rotifers in general are good indicators for saprobity (Sladecek 1983).*

S2) Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1
Not significantly	0 √
Unknown	U

S3) Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0 √
Unknown	U

- *This species is not known to negatively affect water quality; however, it feeds on the colloids that are suspended in the water. Therefore, it might enhance the water quality instead (Sladecek 1983).*

S4) Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

- *This species is not known to harm any economic sectors.*

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

Socio-Economic Impact Total	**0**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**Low**
1	0	
0	≥2	Unknown
1	≥1	

POTENTIAL BENEFICIAL EFFECT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular effect. An "Unknown" response is appropriate if the potential for a particular effect might be inferred but has not been explicitly reported or if there is an unresolved debate about a particular effect.

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1
Not significantly	0 √
Unknown	U

B2) Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?

Yes, it is economically important to at least one of these industries	6
Yes, but its economic contribution is small	1
Not significantly	0 √
Unknown	U

B3) Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local communities and/or tourism	6

It is sometimes employed recreationally, but adds little value to local communities or tourism	1
Not significantly	0 √
Unknown	U

- *There is no documented recreational value for this species.*

B4) Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR It is potentially important to medicine or research and is currently being or scheduled to be studied	1
Not significantly	0 √
Unknown	U

- *This species has no significant value in medicine or research.*

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1
Not significantly	0 √
Unknown	U

- *Colloids (suspended solids) and wastewater provide common food sources for this species (Sledecek 1983).*

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1
Not significantly	0 √
Unknown	U

- *This species is important as a food source for fishes (Geng et al. 2005), including for fish larvae (e.g., carp larvae) (Valdenberg et al. 2006).*
- *Larval instar of Glassworm* Chaoborus crystallinus *feed on* Filinia cornuta *(Swift 1992).*

Beneficial Effect Total	**0**
Total Unknowns (U)	**0**

<table>
<tr><th colspan="3">Scoring</th></tr>
<tr><th>Score</th><th># U</th><th>Impact</th></tr>
<tr><td>>5</td><td>Any</td><td>High</td></tr>
<tr><td>2-5</td><td>Any</td><td>Moderate</td></tr>
<tr><td>0</td><td>0-1</td><td rowspan="2"><u>Low</u></td></tr>
<tr><td>1</td><td>0</td></tr>
<tr><td>0</td><td>≥2</td><td rowspan="2">Unknown</td></tr>
<tr><td>1</td><td>≥1</td></tr>
</table>

Scientific Name: *Filinia passa*
O.F. Muller, 1786

Common Name:

Synonyms:

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: Unlikely

Hitchhiking/fouling: Unlikely

Unauthorized intentional release: Unlikely

Stocking/planting/escape from recreational culture: Unlikely

Escape from commercial culture: Unlikely

Transoceanic shipping: High

***Filinia passa* has a high probability of introduction to the Great Lakes (Confidence level: High).**

Potential pathway(s) of introduction: Transoceanic Shipping

Rotifer identified as having high probability of invasion if introduced to the Great Lakes. Potential pathway of introduction is ballast sediment. The resting stage of this species may survive transport under harsh conditions such as in ballast tanks and ballast sediment (Bailey et al. 2005, Johengen et al. 2005). NOTE: This species is identified as having lower probability of invasion due to the effects of ballast water exchange or flushing (Briski et al. 2010).

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100
No, this species does not occur near waters connected to the Great Lakes basin and/or is not mobile or able to be transported by wind or water.	0 √
Unknown	U

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0 √
Unknown	U

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a) Is this species sold at aquarium/pet/garden stores ("brick & mortar" or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100
No, this species this species is rarely/never sold.	0 √
Unknown	U

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5

This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0 √
Unknown	U

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is likely to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces), this activity may occur within 20 km of the basin because of the species' popularity/value.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100
No, this species is not commercially cultured in or transported through the Great Lakes region.	0 √
Unknown	U

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity	Score x 0.5

involves transport of live organisms on/across the Great Lakes.	
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U

<u>POTENTIAL INTRODUCTION VIA SHIPPING</u>

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80 √
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40
No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0
Unknown	U

- Filinia passa *was found to be a habitat match to the Great Lakes because it hatched in a 0% medium during lab experiments that was considered a match to the habitat of the Great Lakes (Bailey et al. 2005).*
- Filinia passa *is capable of living in the abiotic conditions of the Great Lakes and also has a broad global distribution and rotifers in general should present the predominant invasion risk to the Great Lakes (Bailey et al. 2005).*

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1 √
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5
Yes, but this species has neither been observed in ballast/fouling ships entering the Great Lakes nor in ports in direct trade with the Great Lakes.	Score x 0.1
No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0
Unknown	U

- *Bailey et al. (2005) studied the resting stages of invertebrates in residual ballast sediments of transoceanic ships as possible vectors to the Great Lakes in which* Filinia passa *occurred on 4 ships out of the possible 35 and had an abundance of 3.5 that emerged from a 40 g sediment samples from the ships it was found.*

Vector Potential Scorecard					
Vector		**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind		**0**	x	**0**	Unlikely
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.		**0**	x	**0**	Unlikely
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)		**0**	x	**0**	Unlikely
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)		**0**	x	**0**	Unlikely
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)		**0**	x	**0**	Unlikely
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling		**80**	x 1	**80**	High
Total Unknowns (U)	**0**	**Confidence Level**		High	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

ESTABLISHMENT POTENTIAL RESULTS

Status: **Not established in North America, including the Great Lakes**

Filinia passa **has a moderate probability of establishment if introduced to the Great Lakes (Confidence level: moderate.)**

Filinia passa has a broad global distribution (Bailey et al 2005) and has been found to be able to grow in laboratory conditions matching Great Lakes abiotic conditions. *Filinia passa* has been found in winter (mean temperature, 3.8°C) in Oder River, Germany (Wolska and Piasecki 2006), indicating that it will likely be able to overwinter in the Great Lakes as well. It is a bacterivore so primary food is readily available in the Great Lakes.

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
	7

- *This species is found in the Oder River (near the Baltic Sea), including the estuarine portion. Therefore, it can survive in higher salinity waters (0.5-2 psu; Radziejewska and Schernewski 2008) and in polluted/eutrophic conditions (Radziejewska and Schernewski 2008). In addition, this area of the river can have a mean winter temperature of 2.3°C and mean summer temperature of 24.1°C (Wolska and Piasecki 2006).*

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9
Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
	7

- Filinia passa *has been found in winter (mean temperature, 2.3˚C) in Oder River, Germany (Wolska and Piasecki 2006).*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9

This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
	4

- Filinia passa *likely has similar diet to* F. longiseta*, which consumes bacteria (Ooms-Wilms et al. 1993)*

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	0
Unknown	U
	U

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
	U

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid	6

establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
	U

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- *This species is found in the Oder River (near the Baltic Sea), including the estuarine portion. Therefore, it can survive in higher salinity waters (0.5-2 psu; Radziejewska and Schernewski 2008) and in polluted/eutrophic conditions (Radziejewska and Schernewski 2008). In addition, this area of the river can have a mean winter temperature of 2.3°C and mean summer temperature of 24.1°C (Wolska and Piasecki 2006).*
- Filinia passa *was found to be a habitat match to the Great Lakes because it hatched in a 0% medium during lab experiments which was considered a match to the habitat of the Great Lakes (Bailey et al. 2005).* F. passa *are capable of living in the abiotic conditions of the Great Lakes and also has a broad global distribution and rotifers in general should present the predominant invasion risk to the Great Lakes (Bailey et al. 2005).*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- Filinia passa *are capable of living in the abiotic conditions of the Great Lakes and also has a broad global distribution and rotifers in general should present the predominant invasion risk to the Great Lakes and found as a habitat match (Bailey et al. 2005).*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	**3**
Scarce (Suitable habitats are rarely found)	0
Unknown	U
	7

- Filinia passa *are capable of living in the abiotic conditions of the Great Lakes and also has a broad global distribution (Bailey et al. 2005)*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0
Unknown	U
	3

- *This species is found in the Oder River (near the Baltic Sea), including the estuarine portion. Therefore, it can survive in higher salinity waters (0.5-2 psu; Radziejewska and Schernewski 2008)*
- *Rotifers such as* F. passa *and* F. longestia *prevailed during warm months specifically June and July and their season dynamics were governed by temperature and presence of large Daphnia individuals. Average minimum and maximum values of abundance(Ind. L^-1) is 53.33 and 253.33 (Michaloudi and Kostecka 2004).*

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9

Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
	5

- *Bacteria are abundant in most* F. passa *habitats.*

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Great Lakes and is not likely to be introduced	-80% total points (at end)
Unknown	U
	9

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes)	6

Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0
Unknown	U
	0

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0
Unknown	U
	-10%

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9
Frequent, moderate inocula	6
Frequent, small inocula OR infrequent, large inocula	3
Infrequent, small or moderate inocula	0
Unknown	U
	3

- *Of all species hatched from residual ballast sediment, Bailey et al. (2005) found* F. passa *to be the second most abundance species.*

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
	4

- Filinia passa *is native to Australia, but is also found in Ukraine, Polish, German and Greek waters (Galkovskaya and Molotkov 2001, Goździejewska and Tucholski 2011, Holst et al. 1998, Michaloudi and Kostecka 2004, Millar 2008)*

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
	4

- *Dates of introductiosns were not found, but based on distribution it appears to spread quite easily.*

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing the establishment and spread of this species)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent the establishment and/or spread of this species	0

Unknown	U
	0

Establishment Potential Scorecard				
Points	**Probability for Establishment**	A. Total Points (pre-adjustment)		69
>100	High	**Adjustments**		
		B. Critical species	A*(1- 0%)	69
51-99	Moderate	C. Natural enemy	B*(1- 10%)	62.1
		Control measures	C*(1- 0%)	62.1
0-50	Low	**Potential for Establishment**		Moderate
# of questions answered as "unable to determine"	**Confidence Level**			
0-1	High	Total # of questions unknown		3
2-5	Moderate			
6-9	Low	Confidence Level		Moderate
>9	Very low			

Section C: Potential for Impact

<u>IMPACT POTENTIAL RESULTS</u>

Environmental: Unknown

Socio-Economic: Low

Beneficial: Low

Current research on the potential environmental impacts to result from *Filinia passa* if introduced to the Great Lakes is inadequate to support proper assessment.

There is insufficient information available to determine whether *Filinia passa* poses a threat to other species or water quality. There are no reports on how it affects or interacts with other species. It is unknown whether this speies alters the physical components of the ecosystem.

There is little or no evidence to support that *Filinia passa* has the potential for significant socio-economic impacts of introduced to the Great Lakes.

It has not been reported that *Filinia passa* poses a threat to human helath or water quality. There is no evidence that this species negatively impacts infrastructure, economic sectors, recreational activities and associated tourism, or the aesthetic appeal of the areas it inhabits.

There is little or no evidence to support that *Filinia passa* has the potential for significant beneficial impacts of introduced to the Great Lakes.

It has been indicated that *Filinia passa* can be used for the control of other organisms or improving water quality. There is no evidence to suggest that this species is commercially, recreationally, or medically valuable. It does not have significant positive ecological impacts.

POTENTIAL ENVIRONMENTAL IMPACT

NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1
Not significantly	0
Unknown	U √

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1
Not significantly	0
Unknown	U √

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in the food web)	6
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival,	1 √

fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	
Not significantly	0
Unknown	U

- *Mesocyclops and Tropcyclops induces de novo spine formation or spine lengthening in several planktonic rotifers. Rotifers that have observed this included* Filinia passa*. The spined phonotypes is a significant reduction in capture and ingestion by invertebrate predators (Thorpe 1977). This is similar to the spiny water flea in regards to the spiny water flea having a sharp spine which is difficult for small fish to eat.*

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0
Unknown	U √

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1
Not significantly	0
Unknown	U √

E6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1
Not significantly	0
Unknown	U √

Environmental Impact Total	**1**
Total Unknowns (U)	**5**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	Low
1	0	
0	≥2	**Unknown**
1	≥1	

POTENTIAL SOCIO-ECONOMIC IMPACT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1
Not significantly	0 √
Unknown	U

S2) Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1
Not significantly	0 √
Unknown	U

S3) Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1

Not significantly	0 √
Unknown	U

S4) Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

Socio-Economic Impact Total	**0**
Total Unknowns (U)	**0**

Scoring

Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**<u>Low</u>**
1	0	

0	≥2	Unknown
1	≥1	

POTENTIAL BENEFICIAL EFFECT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular effect. An "Unknown" response is appropriate if the potential for a particular effect might be inferred but has not been explicitly reported or if there is an unresolved debate about a particular effect.

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1
Not significantly	0 √
Unknown	U

B2) Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?

Yes, it is economically important to at least one of these industries	6
Yes, but its economic contribution is small	1
Not significantly	0 √
Unknown	U

B3) Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local communities and/or tourism	6
It is sometimes employed recreationally, but adds little value to local communities or tourism	1
Not significantly	0 √
Unknown	U

B4) Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR It is potentially important to medicine or research and is currently being or scheduled to be studied	1
Not significantly	0 √

Unknown	U

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1
Not significantly	0 √
Unknown	U

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1
Not significantly	0 √
Unknown	U

Beneficial Effect Total	**0**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**<u>Low</u>**
1	0	
0	≥2	Unknown
1	≥1	

A.13 Plants

Scientific Name: *Crassula helmsii*
Cockayne

Common Name: Swamp Stone-crop, New Zealand Pygmy Weed

Synonyms: *Tillaea recurva, Crassula recurva, Tillaea helmsii*

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: Unlikely

Hitchhiking/fouling: Unlikely

Unauthorized intentional release: Unknown

Stocking/planting/escape from recreational culture: Unlikely

Escape from commercial culture: Unlikely

Transoceanic shipping: Unlikely

***Crassula helmsii* has an unknown probability of introduction to the Great Lakes (Confidence level: Moderate).**

Potential pathway(s) of introduction: Unauthorized Intentional Release

This species has been found for sale at large outdoor stores (e.g., Lowe's Hardware mistakenly sold it under another name in Florida), as well as recommended for hobbyists online. It is unknown, however, if it is being bought and sold in the Great Lakes region.

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100
No, this species does not occur near waters connected to the Great Lakes basin and/or is not mobile or able to be transported by wind or water.	0 √
Unknown	U

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0 √
Unknown	U

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a) Is this species sold at aquarium/pet/garden stores ("brick & mortar" or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100 √
No, this species this species is rarely/never sold.	0
Unknown	U

- *This species has been found for sale at large outdoor stores (e.g., Lowe's Hardware mistakenly sold it under another name in Florida), as well as recommended for hobbyists online. It is unknown, however, if it is being bought and sold in Michigan or the Great Lakes region.*

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1
Unknown	U √

- *This species has been found for sale at large outdoor stores (Lowe's Hardware), as well as recommended for hobbyists online. It is unknown, however, if it is being bought and sold in Michigan or the Great Lakes region.*

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0 √
Unknown	U

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is likely to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces), this activity may occur within 20 km of the basin because of the species' popularity/value.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100
No, this species is not commercially cultured in or transported through the Great Lakes region.	0 √
Unknown	U

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40
No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0 √
Unknown	U

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5
Yes, but this species has neither been observed in ballast/fouling ships entering the Great Lakes nor in ports in direct trade with the Great Lakes.	Score x 0.1
No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0
Unknown	U

Vector Potential Scorecard					
Vector		**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind		**0**	x	**0**	Unlikely
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.		**0**	x	**0**	Unlikely
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)		**100**	x U	**U**	Unknown
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)		**0**	x	**0**	Unlikely
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)		**0**	x	**0**	Unlikely
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling		**0**	x	**0**	Unlikely
Total Unknowns (U)	**2**	**Confidence Level**		Moderate	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

ESTABLISHMENT POTENTIAL RESULTS

Status: **Established in North America, but not the Great Lakes**

***Crassula helmsii* has a moderate probability of establishment if introduced to the Great Lakes (Confidence level: High).**

Crassula helmsii has a broad physiological tolerance and this range suggest it would fair just fine in the Great Lakes. *C. helmsii* can overwinter in temperatures of 0°C. In the United Kingdom, it is highly invasive and outcompetes many native plant species by forming dense smothering mats of vegetation; this same occurrence would happen in the Great Lakes region if introduced. *C. helmsii* reproduces very easily and would spread once introduced.

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
	8

- *This species can tolerate drying for extended periods (Kirby 1965)*
- C. helmsii *survives in poor phosphorus conditions (3.4 µg/L), to rich phosphorus conditions (529 µg/L), though more limited spread in poor phosphorus (Brunet 2002).*
- C. helmsii *survives in poor potassium conditions (0.16 µg/L), to rich potassium conditions (8.56 µg/L), though more limited spread in poor potassium (Brunet 2002).*
- *This species inhabits shallow acidic seasonal pools, to more alkaline, nutrient-rich lakes (Dawson and Warman 1987).*
- *This species appears to do better in high light, but has also been found despite shading (Dawson and Warman 1987).*
- C. helmsii *has temperature range of 0-25°C, including extended periods under snow (EPPO 2007, Kirby 1965).*

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9
Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0

Unknown	U
	8

- C. helmsii *has a temperature range of 0-25°C, including extended periods under snow (Kirby 1965, EPPO 2007).*
- *This species can withstand temperatures up to -6°C (Leach and Dawson 1999).*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
	0

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	0
Unknown	U
	9

- *In some areas of the United Kingdom this species is highly invasive and it out-competes many native plant species by forming dense smothering mats of vegetation (Bridge 2005).*
- C. helmsii *shows extreme competitiveness, dominates many sites, and can cover the entire water surface (Brunet 2002).*
- C. helmsii is v*ery tolerant of herbicides (Dawson 1996).*
- C. helmsii *has aggressive competition with other aquatic species to their near exclusion, originally observed in 1920s with Nympizaea (Swale and Belcher 1982) but more recently with* Elodea *spp. (Cockerill 1979), with natural flora in three areas including the New Forest (A. Byfield; 1984 and pers. comm.), and with the rarer Potomogeton spp. (M. Briggs, pers. comm.) (Dawson and Warman 1987).*
- *The invasiveness of this species may result, in part, from Crassulacean acid metabolism, which confers a competitive advantage in relation to growth through carbon conservation (Klavsen and Maberly 2009).*
- C. helmsii *suppresses germination of other species up to 83%, yet there was no effect on seed back and no loss of plant species on four ponds in England. However, the experiment was over a limited time scale (Langdon et al. 2004).*

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
	8

- C. helmsii *propagates via vegetative fragmentation of fragments as small as 1cm (Brunet 2002).*
- *The natural change in branching pattern of this species in the autumn (or shortening days) produces many short laterals with many leaves ('turions') which separate readily from the parent and are dispersed by wind and water current. However, they seem not to sink but collect around the shores of the water body (Dawson and Warman 1987).*

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
	7

- C. helmsii *propagates via vegetative fragmentation of fragments as small as 1cm (Brunet 2002).*
- *The natural change in branching pattern of this species in the autumn (or shortening days) produces many short laterals with many leaves ('turions') which separate readily from the parent and are dispersed by wind and water current. However, they seem not to sink but collect around the shores of the water body (Dawson and Warman 1987).*

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	7

- *In its native range (Australia), air temperatures range from -6-30°C . The invaded range (Belgium, Denmark, France, Germany, Netherlands, United Kingdom) includes areas with very a similar climate.*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	6

- *This species inhabits freshwater areas, with a range of nutrient levels. It is found in waters with pH from 4.29-7.83, and alkalinity from 0-0.92 m.eq/L. These ranges include conditions found in the Great Lakes.*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0
Unknown	U
	6

- C. helmsii *propagates inhabits the margins and shallow waters of freshwater lakes and ponds (Bridge 2005).*
- *This species inhabit ponds, lakes, gravel pits and other static water bodies; also, streams with low flow (Brunet 2002).*
- *This species substrates include gravel, mud/silt, clay, and sand (Brunet 2002).*
- C. helmsii *can inhabit a range of depths: from drying soils to submerged depths of 3 m (Dawson 1996).*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0
Unknown	U
	4

- *This species can withstand warm water temperatures, so climate change may benefit. However, climate change may also hinder this species, as it is adapted to take advantage of low CO_2 conditions.*

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
	9

- C. helmsii *is an autotroph.*

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6

Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Great Lakes and is not likely to be introduced	-80% total points (at end)
Unknown	U
	9

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes)	6
Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0
Unknown	U
	0

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)

Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0
Unknown	U
	0

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9
Frequent, moderate inocula	6
Frequent, small inocula OR infrequent, large inocula	3
Infrequent, small or moderate inocula	0
Unknown	U
	U

- *This depends on introductions from aquarium or pond hobbyists, which is unknown.*

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
	5

- C. helmsii is *native to New Zealand and Australia (Brunet 2002).*
- *This species was introduced to the United Kingdom (Bridge 2005).*
- *It was also introduced to Belgium, Denmark, France, Germany, Netherlands (EPPO 2007).*

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6

Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
	5

- C. helmsii *was introduced to the United Kingdom in 1956, and has since spread throughout the British Isles (Brunet 2002).*

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing the establishment and spread of this species)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent the establishment and/or spread of this species	0
Unknown	U
	0

Establishment Potential Scorecard				
Points	**Probability for Establishment**	A. Total Points (pre-adjustment)		91
		Adjustments		
>100	High	B. Critical species	A*(1- 0%)	91
51-99	Moderate	C. Natural enemy	B*(1- 0%)	91
		Control measures	C*(1- 0%)	91
0-50	Low	**Potential for Establishment**		Moderate
# of questions answered as "unable to determine"	**Confidence Level**			
0-1	High	Total # of questions unknown		1
2-5	Moderate			
6-9	Low	Confidence Level		High
>9	Very low			

Section C: Potential for Impact

IMPACT POTENTIAL RESULTS

Environmental: High

Socio-Economic: Moderate

Beneficial: Low

***Crassula helmsii* has the potential for high environmental impact if introduced to the Great Lakes.**

Crassula helmsii suppresses surrounding epiphytic and planktonic algae more than the effect of shade (Brunet 2002). This species has negatively affected the breeding success of the protected great crested newt *Triturus cristatus* (Watson 1999). In some areas of the United Kingdom, *C. helmsii* is highly invasive and outcompetes native plant species by forming dense smothering mats of vegetation (Bridge 2005). *Crassula helmsii* shows extreme competitiveness, dominates many sites, and can cover the entire water surface (Brunet 2002) and is very tolerant of herbicides (Dawson 1996).

***Crassula helmsii* has the potential for moderate socio-economic impact if introduced to the Great Lakes.**

Crassula helmsii can clog drainage ditches (EPPO 2007) and can impact recreational use (EPPO 2007).

There is little or no evidence to support that *Crassula helmsii* has the potential for significant beneficial impacts if introduced to the Great Lakes.

It has not been indicated that *Crassula helmsii* can be used for the control of other organisms or improving water quality. There is no evidence to suggest that this species is commercially, recreationally, or medically valuable. It does not have significant positive ecological impacts.

POTENTIAL ENVIRONMENTAL IMPACT

NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1
Not significantly	0 √
Unknown	U

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6 √
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1
Not significantly	0
Unknown	U

- C. helmsii *suppresses surrounding epiphytic and planktonic algae more than the effect of shade (Brunet 2002).*
- *Has negatively affected the breeding success of the protected great crested newt Triturus cristatus (Watson 1999).*
- *In some areas of the United Kingdom this species is highly invasive and it out-competes many native plant species by forming dense smothering mats of vegetation (Bridge 2005).*
- C. helmsii *shows extreme competitiveness, dominates many sites, and can cover the entire water surface (Brunet 2002).*
- *This species is very tolerant of herbicides (Dawson 1996).*
- C. helmsii *has aggressive competition with other aquatic species to their near exclusion, originally observed in 1920s with Nympizaea (Swale and Belcher 1982) but more recently with* Elodea *spp. (Cockerill 1979), with natural flora in three areas including the New Forest (A. Byfield pers. comm., Byfield 1984), and with the rarer Potomogeton spp. (M. Briggs, pers. comm.) (Dawson and Warman 1987).*
- *This species invasiveness may result, in part, from Crassulacean acid metabolism, which confers a competitive advantage in relation to growth through carbon conservation (Klavsen and Maberly 2009).*
- C. helmsii *suppresses germination of other species up to 83%, yet there was no effect on seed back and no loss of plant species on four ponds in England. However, the experiment was over a limited time scale (Langdon et al. 2004).*

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in the food web)	6
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	1
Not significantly	0 √
Unknown	U

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6

Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0 √
Unknown	U

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1
Not significantly	0 √
Unknown	U

E6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1
Not significantly	0
Unknown	U √

- *This species shows extreme competitiveness, dominates many sites, and can cover the entire water surface (Brunet 2002) - it may shade benthic habitats.*

Environmental Impact Total	**6**
Total Unknowns (U)	**1**

Scoring		
Score	# U	**Impact**
>5	Any	<u>**High**</u>
2-5	Any	Moderate
0	0-1	Low
1	0	

0	≥2	Unknown
1	≥1	

POTENTIAL SOCIO-ECONOMIC IMPACT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1
Not significantly	0 √
Unknown	U

S2) Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1 √
Not significantly	0
Unknown	U

- C. helmsii *can clog drainage ditches (EPPO 2007).*

S3) Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0 √
Unknown	U

S4) Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6
Yes, but negative consequences have been small	1 √
Not significantly	0
Unknown	U

- C. helmsii *can impact recreational use (EPPO 2007).*

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6
Yes, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

Socio-Economic Impact Total	**2**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	**Moderate**
0	0-1	Low
1	0	
0	≥2	Unknown
1	≥1	

POTENTIAL BENEFICIAL EFFECT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular effect. An "Unknown" response is appropriate if the potential for a particular effect might be inferred but has not been explicitly reported or if there is an unresolved debate about a particular effect.

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1
Not significantly	0 √
Unknown	U

B2) Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?

Yes, it is economically important to at least one of these industries	6
Yes, but its economic contribution is small	1
Not significantly	0 √
Unknown	U

B3) Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local communities and/or tourism	6
It is sometimes employed recreationally, but adds little value to local communities or tourism	1
Not significantly	0 √
Unknown	U

B4) Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR It is potentially important to medicine or research and is currently being or scheduled to be studied	1
Not significantly	0 √
Unknown	U

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1
Not significantly	0 √
Unknown	U

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1
Not significantly	0 √
Unknown	U

Beneficial Effect Total	**0**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**<u>Low</u>**
1	0	
0	≥2	Unknown
1	≥1	

Scientific Name: *Egeria densa*
Planchon

Common Name: Brazilian Waterweed

Synonyms: *Anacharis densa* (Planch.) Victorin, *Elodea densa* (Planch.) Caspary, *Philotria densa* (Planch.) Small & St. John

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: Unknown

Hitchhiking/fouling: Moderate

Unauthorized intentional release: High

Stocking/planting/escape from recreational culture: Low

Escape from commercial culture: Unknown

Transoceanic shipping: Unlikely

***Egeria densa* has a high probability of introduction to the Great Lakes (Confidence level: Low).**

Potential pathway(s) of introduction: Dispersal, Hitchhiking/Fouling, Unauthorized Intentional Release, Escape from Recreational and Commercial Culture

Egeria densa is one of the most common species sold in the Montreal aquarium trade (Cohen et al. 2007). The sale and transport of *E. densa* is prohibited in Illinois, Indiana, Michigan, Minnesota, and Wisconsin (GLPANS 2012); but there are no regulations on the sale or transport of *E. densa* in New York, Ohio, Ontario, Pennsylvania, or Quebec. A survey performed from 2002 to 2003 on aquarium and pet stores near Lakes Erie and Ontario found that 35% of stores surveyed sold *E. densa* (Rixon et al. 2005). Due to the availability of *E. densa* in stores near the Great Lakes, and the ability of the species to overwinter, Rixon et al. (2005) predicted that it has the potential to be introduced to the Great Lakes. Based on the number of aquarium stores in Montreal, Quebec that sold *E. densa*, the number of *E. densa* sold by each store, and the disposal pathways for aquatic plants, Cohen et al. (2007) estimates that 188 *E. densa* individuals are released into the St. Lawrence Seaway each year.

This species may be transported by hitchhiking on recreational gear; *E. densa* grows in thick mats that can become entangled on boat propellers and trailer wheels, or can be captured in bilge water (Washington State Department of Ecology 2013). Attached fragments can be transported between water bodies. *Egeria densa* is not known to be taken up in ballast water.

As a popular ornamental plant, *E. densa* is planted in water gardens (INDNR 2013) and can be purchased (e.g. Green Vista Water Gardens) in Ohio; however, there is not enough information available to determine the frequency of *E. densa* plantings. *Egeria densa* is cultured in Florida for the ornamental aquatic plant industry (Fenner); however, there is no indication that *E. densa* is commercially cultured in the Great Lakes region.

Egeria densa was first reported outside of its native range in 1893 in Long Island, New York (Yarrow et al. 2009). *Egeria densa* is a known nuisance species in California, Oregon, and Washington (California State Parks 2014, Washington State Department of Ecology 2013). *Egeria densa* has been reported in Powderhorn Lake, Minnesota (City of Minneapolis 2013) and Griffy Lake, Indiana, but has been controlled and eradicated. *Egeria densa* occurs private ponds in Lake County, Illinois (Illinois Database of Aquatic Non-native Species 2014, Lake County Health Department and Community Health Center 2009, New Invaders Watch Program 2014), which is near Lake Michigan; however, dispersal from these ponds is limited because it does not occur in waters connected to the Great Lakes.

Nonindigenous *E. densa* populations in Río Cruces, Chile have similar genotypes as populations in Western Oregon, suggesting that the two populations experienced similar bottlenecking events at introduction, or there is a lack of genetic diversity in the native population (Carter and Sytsema 2001).

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100 √
No, this species does not occur near waters connected to the Great Lakes basin and/or is not mobile or able to be transported by wind or water.	0
Unknown	U

- *A study of the Montreal, Quebec aquarium trade estimates that up to 188* E. densa *plants enter the St. Lawrence Seaway each year (Cohen et al. 2007). While this estimate does not represent actual sightings, it represents a risk of introduction into the St. Lawrence Seaway, which then connects with the Great Lakes.*
- *The plant is capable of vegetative reproduction from stem fragments containing double nodes (Washington State Department of Ecology 2013). As such, new plants may form from fragments carried by water currents.*
- Egeria densa *has been reported in Powderhorn Lake, Minnesota (City of Minneapolis 2013), and Griffy Lake, Indiana, but has been controlled and eradicated.*
- Egeria densa *occurs private ponds in Lake County, Illinois (Illinois Database of Aquatic Non-native Species 2014, Lake County Health Department and Community Health Center 2009, New Invaders Watch Program 2014), which is near Lake Michigan.*

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25

Unknown	U √

- *The location of the current closest population of* E. densa *is not known, but previous records have been documented in Great Lakes states, including Minnesota and Indiana:*
    - *This species was found in 2007 in Powderhorn Lake, Minneapolis, MN but has been eradicated and not found since (City of Minneapolis 2013).*
    - *In Indiana, a 2004 infestation of Griffy Lake was subsequently treated and has not been detected since 2008 (S. Cotter, City of Bloomington Parks and Recreation Department, Natural Resources Manager, pers. comm. 2012, Long 2008).*
- *More distant but persistent populations of this species can be found in California and Washington state:*
    - *In Long Lake, Washington,* E. densa *comprised approximately 90% of the aquatic vegetation and persisted despite of 19 years of management that included a drawdown and harvesting (Jacoby et al. 2001).*
    - *Subject to an intensive chemical control program,* E. densa *was documented in 2000 as covering 3,900 acres of California's Sacramento-San Joaquin Delta and spreading at a rate of 100 acres/year (California Department of Boating and Waterways 2006).*
- Egeria densa *occurs in Lake County, Illinois (Illinois Database of Aquatic Non-native Species 2014, Lake County Health Department and Community Health Center 2009, New Invaders Watch Program 2014), which is near Lake Michigan; however, it is unlikely this occurrence of this species is in a water body connected to the Great Lakes. Thus, it occurs within 100 km of the Great Lakes basin, but dispersal to the basin is blocked.*

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100 √
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0
Unknown	U

- *This plant often grows in dense mats, becoming entangled on boat propellers and trailer wheels or captured in bilge water. Attached fragments can then be transported between water bodies (Washington State Department of Ecology 2013).*

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5√
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1
Unknown	U

- *The location of the current closest population of* E. densa *is not known, but previous records have been documented in Great Lakes states, including Minnesota and Indiana:*
    - *This species was found in 2007 in Powderhorn Lake, Minneapolis, MN but has been eradicated and not found since (City of Minneapolis 2013).*
    - *In Indiana, a 2004 infestation of Griffy Lake was subsequently treated and has not been detected since 2008 (S. Cotter, City of Bloomington Parks and Recreation Department, Natural Resources Manager, pers. comm. 2012; Long 2008).*
- *More distant but persistent populations of this species can be found in California and Washington state:*

- *In Long Lake, Washington,* E. densa *comprised approximately 90% of the aquatic vegetation and persisted despite of 19 years of management that included a drawdown and harvesting (Jacoby et al. 2001).*
- *Subject to an intensive chemical control program,* E. densa *was documented in 2000 as covering 3,900 acres of California's Sacramento-San Joaquin Delta and spreading at a rate of 100 acres/year (California Department of Boating and Waterways 2006).*

- Egeria densa *occurs in Lake County, Illinois (Illinois Database of Aquatic Non-native Species 2014, Lake County Health Department and Community Health Center 2009, New Invaders Watch Program 2014), which is near Lake Michigan; however, it is unlikely this occurrence of this species is in a water body connected to the Great Lakes. Thus, it occurs within 100 km of the Great Lakes basin, but dispersal to the basin is blocked.*

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a) Is this species sold at aquarium/pet/garden stores ("brick & mortar" or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100 √
No, this species this species is rarely/never sold.	0
Unknown	U

- Egeria densa *is sold in aquarium stores (Cohen et al. 2007), online retailers (e.g. Petco), and biological supply companies (e.g., Carolina.com).*

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1 √
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1
Unknown	U

- Egeria densa *is one of the most common species sold in the aquarium trade (Cohen et al. 2007).*
- *However, sale of this species is banned in Minnesota (USDA Plant Industry Division 2005), Indiana (IN NRC 2012), Illinois (USDA Plant Industry Division 2005), Michigan (USDA Plant Industry Division 2005), and Wisconsin (WIDNR 2012).*
- *This plant's sale is not regulated in New York, Ohio, or Pennsylvania (USDA Plant Industry Division 2005).*
- *The sale of* E. densa *does not appear to be regulated in Ontario or Quebec, despite attempts to find resources on this subject.*

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the	100 √

Great Lakes region.	
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0
Unknown	U

- Egeria densa *is a popular submerged oxygenating pond plant (Haramoto and Ikusima 1988) and is likely planted in the Great Lakes region.*
- *This plant is also frequently mislabeled at pet stores and sold under unregulated plant names (June-Wells 2012).*
- *As an ornamental plant,* E. densa *is planted in water gardens (INDNR 2013).*

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is <u>likely</u> to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces), this activity <u>may</u> occur within 20 km of the basin because of the species' popularity/value.	Score x 0.25 √
Unknown	U

- *This plant can be purchased via the Internet (e.g., greenvista.com) from states in the Great Lakes basin where its sale is unregulated (e.g., Ohio) and planted in states that have regulations. Many websites that sell this plant leave it up to the buyer to check state regulations (e.g., plantedaquariumcentral.com) and may not post current state regulations.*
- *As an ornamental plant,* E. densa *is planted in water gardens (INDNR 2013).*

<u>POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE</u>

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100
No, this species is not commercially cultured in or transported through the Great Lakes region.	0
Unknown	U √

- *This species has been maintained in in-ground tanks in the state of Michigan as part of an overwintering study (MI DEQ 2013).*
- Egeria densa *is also capable of being sold from companies culturing it (e.g., greenvista.com) and transporting it to and from states in the Great Lakes basin. For example, Ohio has no regulations on this plant and therefore its transportation from that part of the basin is unlikely to be monitored.*

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes	Score x 0.75

tributaries or connecting waters, or within 20 km of the Great Lakes basin.	
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U √

- *The use of this plant in experiments in Michigan is highly regulated (Michigan.gov 2007).*
- *Live transport of this plant within the Great Lakes basin or within 20 km of its connecting waters is capable of occurring due to levels of state regulations varying throughout the Great Lakes basin.*

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40
No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0 √
Unknown	U

- *This plant is not likely to be taken up in the ballast of transoceanic ships.*
- *This species is capable of adapting to many of the possible changes in its environment. It endures well in low light conditions (Lara et al. 2002). It also has the ability to overwinter (Rixon et al. 2005).*
- *This plant can tolerate a wide range of nutrient levels (Yarrow et al. 2009).*
- *The ability of this plant to tolerate many different environmental conditions makes it capable of living on or in boats and boating gear for long periods of time (Yarrow et al. 2009).*
- *This plant cannot survive in saltwater, but it can tolerate water with a salinity concentration of 8 ppt (Hauenstein and Ramirez 1986).*

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5
Yes, but this species has neither been observed in ballast/fouling ships entering the Great Lakes nor in ports in direct trade with the Great Lakes.	Score x 0.1

No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0
Unknown	U

Vector Potential Scorecard					
Vector		**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind		**100**	x U	**U**	Unknown
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.		**100**	x 0.5	**50**	Moderate
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)		**100**	x 1	**100**	High
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)		**100**	x 0.25	**25**	Low
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)		**U**	x U	**U**	Unknown
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling		**0**	x	**0**	Unlikely
Total Unknowns (U)	**3**	**Confidence Level**		Low	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

ESTABLISHMENT POTENTIAL RESULTS

Status: Established in North America, but not including the Great Lakes.

***Egeria densa* has a moderate probability of establishment if introduced to the Great Lakes (Confidence level: High).**

Egeria densa has broad physiological tolerances. It can tolerate low light conditions (Lara et al. 2002). Although a tropical plant, it is able to adapt to seasonal changes and overwinter (INDNR 2013, Parsons and Cuthbertson 2001, Rixon et al. 2005, Yarrow et al. 2009). It can tolerate low levels of CO_2 (Casati et al. 2000), nitrogen, phosphorus, and nutrients (Yarrow et al. 2009). This species can survive in waters with salinities up to 8 ppt (Hauenstein and Ramirez 1986).This species is known to have a relatively fast growth rate (Yarrow et al. 2009).

Moreover, the introduced ranges of *Egeria densa* have similar climate and abiotic conditions as the Great Lakes. *Egeria densa* has established near the Great Lakes previously (e.g. Griffy Lake, Indiana), in areas that have similar water temperature and dissolved oxygen levels (Long 2008, NOAA CoastWatch 2014). This species can survive in freshwater habitats of varying temperatures, light levels, and CO_2 levels; thus suitable habitats are readily available in the Great Lakes region. Turbidity and nutrient levels of the Great Lakes is likely suitable for *E. densa* to obtain sufficient light, phosphorus, and nitrogen. It is likely that *Egeria densa* will benefit from the effects of climate change, including warmer temperatures and shorter duration of ice cover. Increased salinization due to climate change may negatively impact this species' establishment if salinities exceed 8 ppt (Hauenstein and Ramirez 1986). Grass Carp preys on *E. densa* and occurs in the Great Lakes region (Anderson et al. 2008, Hoshovsky and Anderson 2001, Parsons and Cuthbertson 2001), but it is not likely that it will prevent the establishment of *E. densa* in the Great Lakes. Each year, it is estimated that 188 *E. densa* individuals enter the St. Lawrence Seaway through disposal of aquarium plants (Cohen et al. 2007).

Egeria densa reproduces asexually via vegetative fragmentation (Hoshovsky and Anderson 2001), which may aid its establishment in the Great Lakes region. This species spreads rapidly by vegetative fragmentation and recreational activities, resulting in dense mats (INDNR 2013).

E. densa has established extensively in 27 countries beyond its native range (Curt et al. 2009). In Australia, *E. densa* spread quickly; over a period of two years, it doubled its biomass and doubled the area it occupied in the Hawkesbury-Nepean River (Roberts et al. 1999). It is difficult to control once established (Yarrow et al. 2009) and it is recommended to correctly identify the plant due to its similarities with native plants (INDNR 2013). Grass Carp is used as a biological control in California (Hoshovsky and Anderson 2001). In Griffy Lake, Indiana, fluridone successfully removed *E. densa*, but also caused the mortality of all aquatic plants (Jones 2006). Physical removal is not recommended as it can result in vegetative fragmentation and encourages dispersal of *E. densa* (Parsons and Cuthbertson 2001).

The model developed by Rixon et al. (2005) predicts that *E. densa* poses a threat to the Great Lakes. *Egeria densa* may have the potential to compete with native species. In the Hawkesbury-Negean River, increased spread of *E. densa* resulted in the displacement and reduced abundance of the native vallisneria *Vallisneria americana* (Roberts et al. 1999). It is suspected that competition for light was responsible for the decline in vallisneria, and that floods were responsible for the rapid spread of *E. densa*.

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
	7

- *This species can survive in salinity levels of up to 8 ppt (Hauenstein and Ramirez 1986).*
- *This species does well in low light conditions. Its apical shoots actually grow more rapidly when there is a lack of light (Lara et al. 2002).*
- *This plant has the ability to adapt to seasonal changes in temperature of 3-35˚C (Yarrow et al. 2009).*
- *This species has considerable adaptations to low CO_2 levels (Yarrow et al. 2009).*
- *This species is capable of obtaining nitrogen or phosphorous nutrients from the sediment or water column and can grow in low levels of these nutrients (Yarrow et al. 2009).*

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9
Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
	6

- *This plant has the ability to adapt to seasonal changes in temperature of 3-35˚C (Yarrow et al. 2009).*
- *This species does well in low light conditions. Its apical shoots actually grow more rapidly when there is a lack of light (Lara et al. 2002).*
- *This species has considerable adaptations to low CO_2 levels (Yarrow et al. 2009).*
- *This species has an overwintering population in Connecticut that has been documented growing rapidly since 2009 (Connecticut Agricultural Experiment Station 2013). This region is closely related to the Great Lakes region.*
- *It has been found overwintering in Indiana (INDNR 2013).*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
	0

- *This species is an autotroph.*

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	0
Unknown	U
	9

- Egeria densa *outcompeted at least three different native plant species between the years 1996-1999 in the Duck Lake Waterways of Washington state (Washington State Department of Ecology 2013).*
- *Brazilian Elodea forms dense monospecific stands that restrict water movement, trap sediment, and cause fluctuations in water quality (Washington State Department of Ecology 2013).*
- Egeria densa *may have the potential to compete with native species. In the Hawkesbury-Negean River, increased spread of* E. densa *resulted in the displacement and reduced abundance of the native vallisneria* Vallisneria americana *(Roberts et al. 1999). It is suspected that competition for light is responsible for the decline in vallisneria, and that floods are responsible for the rapid spread of* E. densa.

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
	6

- *This aquatic plant species has a high fecundity (WIDNR 2013).*

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
	6

- *This plant produces via vegetative reproduction in the United States even though it is a dioecious plant. Only male plants have been recorded in North America (Robinson 2007); therefore, there is no seed reproduction outside of its native range.*

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	7

- *This species has been known to establish in the temperate and subtropical regions of 27 different countries (Curt et al. 2009).*
- *This plant is established in 40 out of 50 United States states, including Illinois, Indiana, Ohio and New York (USDA NRCS 2013).*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9

Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	7

- *Brazilian elodea is native to the central Minas Geraes region of Brazil and to the coastal areas of Argentina and Uruguay (Washington State Department of Ecology 2013).*
- *Brazilian elodea has also spread to New Zealand, Australia, Hawaii, Denmark, Germany, France, Japan, and Chile. In the United States, this plant has spread to fresh inland waters from Washington to Massachusetts, California, and Florida (Washington State Department of Ecology 2013).*
- *This plant is highly plastic depending on environmental conditions (Washington State Department of Ecology 2013).*
- *This species has been known to establish in the temperate and subtropical regions of 27 different countries (Curt et al. 2009).*
- *This plant has established itself in 40 out of 50 of the states in the United States (USDA NRCS 2013).*
- *Many of the abiotic factors in the introduced as well as native area are similar to the Great Lakes.*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0
Unknown	U
	9

- *This plant can grow in depths of up to 20 ft and drifting (Washington State Department of Ecology 2013).*
- *This plant has the ability to adapt to seasonal changes in temperature of 3-35˚C (Yarrow et al. 2009).*
- *This species does well in low light conditions. Its apical shoots actually grow more rapidly when there is a lack of light (Lara et al. 2002).*
- *This species has considerable adaptations to low CO_2 levels (Yarrow et al. 2009).*
- Egeria densa *is likely to establish in Great Lakes marshes (MIDNR 2013).*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Great Lakes a	3

better environment for establishment and spread of this species)	
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0
Unknown	U
	8

- *This species can survive in salinity levels only up to 8 ppt (Hauenstein and Ramirez 1986). Therefore, increased salinization would negatively impact the establishment of* Egeria densa.
- *Changed water flow and waves increase fragmentation (California Invasive Plant Council 2015). Therefore, altered streamflow patterns might aid in establishment of this plant.*
- *This plant initiates growth at 10˚C (Washington State Department of Ecology 2013). Therefore, higher temperatures and less ice cover in the Great Lakes region would aid this plant in reproduction.*

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
	8

- *This species is capable of obtaining nitrogen or phosphorous nutrients from the sediment or water column and can grow in low levels of these nutrients (Yarrow et al. 2009).*
- *This species does well in low light conditions. Its apical shoots actually grow more rapidly when there is a lack of light (Lara et al. 2002).*

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	3

Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Great Lakes and is not likely to be introduced	-80% total points (at end)
Unknown	U
	9

- *There is no critical species required by the species being assessed.*

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes)	6
Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0
Unknown	U
	0

- *There are no known species in the Great Lakes that can aid in the establishment of this species.*

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0

Unknown	U
	-10%

- *The Grass Carp has been known to consume* Egeria densa *(GISD 2005a).*
- *Triploid (sterile) Grass Carp are in four out of five of the Great Lakes already, but in relatively low abundance (Congress Research Service 2012).*
- *Grass Carp is used as a biological control in California (Hoshovsky and Anderson 2001).*

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9
Frequent, moderate inocula	6
Frequent, small inocula OR infrequent, large inocula	3
Infrequent, small or moderate inocula	0
Unknown	U
	7

- *A study of the Montreal, Quebec aquarium trade estimates that up to 188* E. densa *plants enter the St. Lawrence Seaway each year (Cohen et al. 2007).*

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
	9

- *This plant is known to have established in 27 countries outside its natural habitat range (Curt et al. 2009).*
- *This plant has established itself in 40 out of 50 United States states (USDA NRCS 2013).*
- *It occurs in Alabama, Arkansas, Colorado, Delaware, Florida, Georgia, New Jersey, New Mexico, North Carolina, Oklahoma, Oregon, Pennsylvania, South Carolina, Tennessee, Texas, Virginia, West Virginia, Mexico, West Indies, Central America (Flora of North America Editorial Committee 2000).*
- Egeria densa *is declared a weed in Tasmania, Australia (Parsons and Cuthbertson 2001) and Argentina (Cabrera Walsh et al. 2013).*

- Egeria densa *has been reported in Bogakain Lake, Bangladesh in 2010 (Alumujaddade Alfasane et al. 2010).*
- *This species is historically introduced outside its native range through the aquarium trade and is considered naturalized in parts of Chile, England, Mexico, New Zealand, and the United States (Cabrera Walsh et al. 2013).*
- *This species occurs in Siera Nevada, Central Valley, central coast of San Francisco Bay, and Jan Jacinto Mountains, California (Hoshovsky and Anderson 2001).*
- *This species occurs in southern Vermont, eastern Massachussetts, and Long Island, New York (Magee and Ahles 2007)*
- *This species has spread in Australia, and it is suspected that large floods caused its rapid spread (Roberts et al. 1999).*
- Egeria densa *has been reported in 2014 in Lake County, Illinois (New Invaders Watch Program 2014, Illinois Database of Aquatic Non-native Species 2014).*

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
	9

- *This species establishes very rapidly once it is introduced (California Invasive Plant Council 2015).*
- *In Australia,* E. densa *spread quickly; over a period of two years, it doubled its biomass and doubled the area it occupied in the Hawkesbury-Nepean River (Roberts et al. 1999). It is suspected that significant flood events during that period were responsible for its rapid spread.*

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing the establishment and spread of this species)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent the establishment and/or spread of this species	0
Unknown	U
	-30%

- *Surveillance and management efforts are currently underway to detect, control and/or eradicate this plant in Michigan (MI DEQ 2013). However, a basin-wide monitoring program is lacking (Dupre 2011).*
- *This species is very hard to eradicate once established (Yarrow et al. 2009).*
- *It is difficult to control* E. densa *and it is recommended to correctly identify the plant due to its similarities with native plants (INDNR 2013).*
- *Grass Carp is used as a biological control in California (Hoshovsky and Anderson 2001).*
- *In Griffy Lake, Indiana, fluridone successfully removed* E. densa*, but also caused the mortality of all aquatic plants (Jones 2006).*
- *Physical removal is not recommended as it can results in vegetative fragmentation and encourages dispersal of* E. densa *(Parsons and Cuthbertson 2001).*

Establishment Potential Scorecard				
Points	**Probability for Establishment**	A. Total Points (pre-adjustment)		107
>100	High	**Adjustments**		
		B. Critical species	A*(1-0%)	107
51-99	Moderate	C. Natural enemy	B*(1-10%)	96.3
		Control measures	C*(1-30%)	67.41
0-50	Low	**Potential for Establishment**		Moderate
# of questions answered as "unable to determine"	**Confidence Level**			
0-1	High	Total # of questions unknown		0
2-5	Moderate			
6-9	Low	Confidence Level		High
>9	Very low			

Section C: Potential for Impact

<u>IMPACT POTENTIAL RESULTS</u>

Environmental: High

Socio-Economic: High

Beneficial: Moderate

***Egeria densa* has the potential for high environmental impact if introduced to the Great Lakes.**

Egeria densa acts as an ecosystem engineer by preventing the resuspension of sediments and controlling light and nutrient availability (Yarrow et al. 2009). The dense growth of *E. densa* can retard water flow and reduce turbidity (Parsons and Cuthbertson 2001). This species can reduce the abundance and diversity of native plant seeds in lake bottoms due to increased sediment accumulation under its weed beds (Hoshovsky and Anderson 2001). *Egeria densa* removes nutrients from the water column, thereby decreasing the standing stock of phytoplankton (Yarrow et al. 2009). Furthermore, *Egeria densa* forms mats that can shade out phytoplankton.

Egeria densa can outcompete native species. In Duck Lake, Washington, *E. densa* displaced native stonewart, elodea, and pondweed in a period of 3 years (Washington State Department of Ecology 2013). In Hawkesbury-Negean River, Australia, evidence suggests that *E. densa* outcompeted native vallisneria (*Vallisneria americana*) for light (Roberts et al. 1999).

Egeria densa is not known to pose a threat to the health of native species. This species is not known to alter predator-prey relationships or genetically affect native populations.

***Egeria densa* has the potential for high socio-economic impact if introduced to the Great Lakes.**

The dense growth of *E. densa* can interfere with irrigation projects, hydroelectric dams, and urban water supply (Hoshovsky and Anderson 2001, Parsons and Cuthbertson 2001). In New Zealand, there was an infestation of *E. densa* in the Wikato River that clogged the water intake pipes resulting in the shut-down of an electrical plant (Washington State Department of Ecology 2013).

Egeria densa can inhibit recreational activities as a nuisance for navigation, fishing, swimming, and water skiing (Washington State Department of Ecology 2013). The removal of *E. densa* is costly; Washington local and state governments spend thousands of dollars each year to control the species. *Egeria densa* may pose a risk to human safety. In 2006, police reports indicate that *E. densa* may have contributed to the death of a physician in San Joaquin County, who drowned after becoming entangled in the “tentacle-like Delta weeds trap” in attempts to save his nephew (Breitler 2006, Victorian Department of Industries 2013).

Egeria densa has gained widespread recognition by parks departments and local and state governments as a nuisance species (GLPANS 2012, Lake County Health Department and Community Health Center 2009, Mcglynn 2013). Resources have been devoted in various cities and states to remove infestations of *E. densa* due to its costly impacts on water supply, infrastructure, and recreation (California State Parks 2014, INDNR 2013).

***Egeria densa* has the potential for moderate beneficial impact if introduced to the Great Lakes.**

It is an ornamental plant for aquariums and small ponds. *Egeria densa* has been recommended as a submerged oxygenator plant for water gardens (Creative Homeowner 2010). *Egeria densa* is also utilized in plant biology classes for students to study photosynthesis (Berkeley 2014).

POTENTIAL ENVIRONMENTAL IMPACT

NOTE: In this section, a “Not significantly” response should be selected if the species has been studied but there have been no reports of a particular impact. An “Unknown” response is appropriate if the species is poorly studied.

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1
Not significantly	0 √
Unknown	U

- Egeria densa *is not known to be hazardous to native species' health.*

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6 √
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1
Not significantly	0
Unknown	U

- *In the Duck Lake waterways of Washington state, within a matter of three years, stonewart, native elodea, and pondweed were displaced completely by thick dense mats of* Egeria densa *(Washington State Department of Ecology 2013).*
- Egeria densa *may have the potential to compete with native species. In the Hawkesbury-Negean River, increased spread of* E. densa *resulted in the displacement and reduced abundance of the native vallisneria* Vallisneria americana *(Roberts et al. 1999). It is suspected that competition for light is responsible for the decline in vallisneria, and that floods are responsible for the rapid spread of* E. densa.

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in the food web)	6
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	1
Not significantly	0 √
Unknown	U

- Egeria densa *is not known to alter predator-prey relationships.*

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6

Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0
Unknown	U √

- *There are no known native populations that have been affected genetically by this plant at the time of this assessment.*

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6 √
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1
Not significantly	0
Unknown	U

- *The dense mats of this plant deplete water oxygen levels and restrict water movement while trapping sediment, leading to fluctuations in water quality (Queensland Department of Agriculture 2011).*
- *The dense growth of* E. densa *can retard water flow (Parsons and Cuthbertson 2001).*
- *This species can reduce the abundance and diversity of native plant seeds in lake bottoms due to increased sediment accumulation under its weed beds (Hoshovsky and Anderson 2001).*
- *This species may remove nutrients from the water column (Yarrow et al. 2009).*

E6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6 √
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1
Not significantly	0
Unknown	U

- Egeria densa *populations in its native range negatively affect many phytoplankton and macrophyte communities (Mazzeo et al. 2003).*
- Egeria densa *grows in dense mats that block light penetration and often displace native plants (Queensland Department of Agriculture 2011).*
- Egeria densa *populations change the available habitat for fish and waterfowl (Queensland Department of Agriculture 2011).*
- Egeria densa *acts as an ecosystem engineer, by preventing the resuspension of sediments, controlling nutrient availability (and phytoplankton growth) by removing nutrients from the water column (Yarrow et al. 2009).*

Environmental Impact Total	**18**
Total Unknowns (U)	**1**

Scoring		
Score	# U	**Impact**
>5	Any	**High**
2-5	Any	Moderate
0	0-1	Low
1	0	
0	≥2	Unknown
1	≥1	

POTENTIAL SOCIO-ECONOMIC IMPACT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6 √
Yes, but negative consequences have not been widespread, long lasting, or severe	1
Not significantly	0
Unknown	U

- *The extreme dense mats of this plant can cause drowning by entanglement (Victorian Department of Industries 2013). The risk would be greatest during highest biomass levels (Victorian Department of Industries 2013).*

S2) Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6 √
Yes, but the costs have been small and are largely reparable or preventable	1
Not significantly	0
Unknown	U

- *In New Zealand, electric generating plants were shut down when fragments of Brazilian Elodea clogged intake structures on the Waikato River (Washington State Department of Ecology 2013).*
- *In Washington State, local and state government and lake residents spend thousands of dollars every year to manage Brazilian Elodea infestations. The cost of the control project in Silver Lake, Cowlitz County is over one million dollars (Washington State Department of Ecology 2013).*

S3) Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0 √
Unknown	U

- Egeria densa *does not appear to have direct effects on water quality in terms of human use.*

S4) Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1 √
Not significantly	0
Unknown	U

- *Dense underwater growth of* E. densa *significantly retards water flow, interfering with irrigation projects, hydroelectric utilities, and urban water supplies (California Invasive Plant Council 2015).*

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6 √
Yes, but negative consequences have been small	1
Not significantly	0
Unknown	U

- *Dense beds of this species can interfere with recreational uses of a waterbody by interfering with navigation, fishing, swimming, and water skiing (Washington State Department of Ecology 2013).*
- *In Washington State, local and state government and lake residents spend thousands of dollars every year to manage Brazilian Elodea infestations. The cost of the control project in Silver Lake, Cowlitz County is over one million dollars (Washington State Department of Ecology 2013).*
- *Dense* E. densa *populations have caused significant negative effects in the fishing industry (NSW DPI 2013b).*
- *These weeds spread downstream and become entangled in nets in large quantities. This affects the viability of the fishery, requiring fishers to move downstream from local and peak trawl grounds. Labor is increased, and travelling and trawl hours are affected (NSW DPI 2013b).*

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6 √
Yes, but negative consequences have been small	1
Not significantly	0
Unknown	U

- *An estimated 1500 acre feet of water storage capacity were lost annually in Lake Marion, South Carolina due to sedimentation caused by Brazilian Elodea growth (Washington State Department of Ecology 2013).*
- Egeria densa *has gained widespread recognition by parks departments and local and state governments as a nuisance species (City of Minneapolis 2013, GLPANS 2012). Resources have been devoted in various cities and states to remove infestations of* E. densa *due to itscostly impacts on water supply, infrastructure, and recreation (California State Parks 2014, INDNR 2013).*

Socio-Economic Impact Total	**25**
Total Unknowns (U)	**0**

Scoring		
Score	# U	**Impact**
>5	Any	**High**
2-5	Any	Moderate
0	0-1	Low
1	0	
0	≥2	Unknown
1	≥1	

POTENTIAL BENEFICIAL EFFECT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular effect. An "Unknown" response is appropriate if the potential for a particular effect might be inferred but has not been explicitly reported or if there is an unresolved debate about a particular effect.

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1
Not significantly	0 √
Unknown	U

- Egeria densa *is not known to act as a biological control.*

B2) Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?

Yes, it is economically important to at least one of these industries	6
Yes, but its economic contribution is small	1 √
Not significantly	0
Unknown	U

- *This plant is sold for aquaculture use in home aquariums and is hardy, making it good for beginners (City of Bloomington (Indiana) 2013).*

B3) Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local communities and/or tourism	6
It is sometimes employed recreationally, but adds little value to local communities or tourism	1 √
Not significantly	0
Unknown	U

- *This plant is sold for aquaculture use in home aquariums and is hardy, making it good for beginners (City of Bloomington (Indiana) 2013).*

B4) Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR It is potentially important to medicine or research and is currently being or scheduled to be studied	1 √
Not significantly	0
Unknown	U

- *It is also a good plant to use in slides to study plant biology (WIDNR 2013).*

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1
Not significantly	0 √
Unknown	U

- Egeria densa *is not known to improve water quality.*

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1
Not significantly	0 √
Unknown	U

- Egeria densa *is not known to have any positive ecological effects.*

Beneficial Effect Total	**3**
Total Unknowns (U)	**0**

<table>
<tr><th colspan="3">Scoring</th></tr>
<tr><th>Score</th><th># U</th><th>Impact</th></tr>
<tr><td>>5</td><td>Any</td><td>High</td></tr>
<tr><td>2-5</td><td>Any</td><td><u>Moderate</u></td></tr>
<tr><td>0</td><td>0-1</td><td rowspan="2">Low</td></tr>
<tr><td>1</td><td>0</td></tr>
<tr><td>0</td><td>≥2</td><td rowspan="2">Unknown</td></tr>
<tr><td>1</td><td>≥1</td></tr>
</table>

Scientific Name: *Eichhornia crassipes*
(Mart.) Solms

Common Name: Water Hyacinth

Synonyms: Common Water-Hyacinth, Floating Water-Hyacinth, *Eichhornia speciosa* Kunth, *Piaropus crassipes* (Mart.) Raf.

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: High

Hitchhiking/fouling: High

Unauthorized intentional release: High

Stocking/planting/escape from recreational culture: Moderate

Escape from commercial culture: Moderate

Transoceanic shipping: Unlikely

***Eichhornia crassipes* has a high probability of introduction to the Great Lakes (Confidence level: High).**

Potential pathway(s) of introduction: Dispersal, Hitchhiking/Fouling, Unauthorized Intentional Release, Escape from Recreational and Commercial Culture

Eichhornia crassipes occurs near waters connected to the Great Lakes basin. This species has been reported to occur in Lake St. Clair and the Detroit River in 2010 (Adebayo et al. 2011). In Michigan, it has been found in Oakland, Livingston, Wayne, and St. Clair counties (Ankney 2012). Clonal individuals of *Eichhornia crassipes* can disperse to new areas when fragments are transported by water (Masterson 2007). *Eichhornia crassipes* forms thick mats that can become entangled on to boat propellers and trailers to be spread to other water bodies. For instance, boats coming from water bodies such as Lake St. Clair or the Detroit River may unintentionally transport *E. crassipes* to Lake Erie.

Eichhornia crassipes is sold at aquarium stores and is sold in the Great Lakes. This species is a popular aquarium plant and is available for purchase in the Great Lakes region. *Eichhornia crassipes* may be frequently introduced into waterways after disposal of the plant from water gardens (Adebayo et al. 2011). In a survey of aquarium stores near Lakes Erie and Ontario, *E. crassipes* was available for purchase in 30% of the stores (Rixon et al. 2005). Title 18 U.S. Code 46 states that it is a violation of the law to knowingly transport *E. crassipes* in interstate commerce, and to sell or purchase the plant (18 U.S.C. § 46). The sale of this species is prohibited in Chicago and Illinois State, but not in Indiana, Michigan, Minnesota, New York, Ohio, Ontario, Pennsylvania, Quebec, or Wisconsin (GLPANS 2012).

Greenhouses within the Great Lakes basin commercially culture and sell *E. crassipes* (e.g. Countryside Greenhouse Allendale, MI) for use in water gardens, thus, it may escape and spread into larger water bodies. Retailers advertise the *E. crassipes* as a good oxygenator plant for ponds.

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100 √
No, this species does not occur near waters connected to the Great Lakes basin and/or is not mobile or able to be transported by wind or water.	0
Unknown	U

- Eichhornia crassipes *has been found in Oakland, Livingston, Wayne, and St. Clair counties in the state of Michigan. These occurrences are located near tributaries that connect to the Great Lakes (Ankney 2012). Eradication at these sites was scheduled to begin in 2013 (Ankney 2012).*
- *Clonal individuals can form through vegetative reproduction of fragmented rosettes, which can then disperse by wind and water movement (Masterson 2007).*

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1 √
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25
Unknown	U

- *Water Hyacinth was found in Lake St. Clair and the Detroit River in 2010 (Adebayo et al. 2011).*

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100 √
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0
Unknown	U

- *This species reproduces chiefly by vegetative means and can quickly form dense floating mats of vegetation.*

- *Dense mats of this species can become entangled in boat propellers and trailers (North American Invasive Species Network 2013).*
- *Seeds are the main source of new infestations and are carried in water and mud (e.g., on machinery or boots), as well as by birds (NSW DPI 2012b)*

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1 √
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1
Unknown	U

- *Water Hyacinth was found in Lake St. Clair and the Detroit River in 2010 (Adebayo et al. 2011).*
- Eichhornia crassipes *has been found in Oakland, Livingston, Wayne, and St. Clair counties in the state of Michigan. These occurrences are located near tributaries that connect to the Great Lakes (Ankney 2012).*

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a) Is this species sold at aquarium/pet/garden stores ("brick & mortar" or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100 √
No, this species this species is rarely/never sold.	0
Unknown	U

- *This species can be purchased from many online retailers (e.g., pondplantsforsale.com).*

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1 √
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1
Unknown	U

- *This plant is both widely popular and frequently sold in the Great Lakes region (WIDNR 2013).*
- *There are no restrictions in the Great Lakes basin banning the sale of this species (USDA NRCS 2013), except for a federal statute banning interstate commerce of this species (18 USC § 46).*
- *The sale of this species is prohibited in Chicago and Illinois State, but not in Indiana, Michigan, Minnesota, New York, Ohio, Ontario, Pennsylvania, Quebec, or Wisconsin (GLPANS 2012).*
- *In a survey of aquarium stores near Lakes Erie and Ontario,* E. crassipes *was available for purchase in 30% of the stores (Rixon et al. 2005).*

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100 √
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0
Unknown	U

- *Greenhouses within the Great* Lakes basin *(e.g.,* Countryside Greenhouse *in* Allendale, MI), *sell this plant and mention its use in their outdoor water gardens.*
- *Retail advertisements also recommend this species as a good oxygenator plants for outdoor ponds.*

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75 √
This activity is likely to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces), this activity may occur within 20 km of the basin because of the species' popularity/value.	Score x 0.25
Unknown	U

- *Greenhouses within the Great Lakes basin (e.g.,* Countryside Greenhouse *in Allendale, MI), sell this plant and mention its use in their outdoor water gardens.*
- *There are no restrictions in the Great Lakes basin banning its sale (USDA NRCS 2013).*

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100 √
No, this species is not commercially cultured in or transported through the Great Lakes region.	0
Unknown	U

- *Greenhouses within the Great Lakes basin (e.g.,* Countryside Greenhouse *in Allendale, MI), sell this plant and mention its use in their outdoor water gardens.*

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75 √
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U

- *Greenhouses within the Great Lakes basin (e.g., Countryside Greenhouse in Allendale, MI), sell this plant and mention its use in their outdoor water gardens.*

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40
No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0 √
Unknown	U

- *Water Hyacinth is tolerant of a wide range of conditions, including frost, but not brackish or sea strength salinity (NSW DPI 2012b).*
- *This species optimum temperature range for growth is 28-30˚C, and it requires ample nitrogen, phosphorus, and potassium (NSW DPI 2012b).*
- *If air temperature remains at 5˚C for 2-3 weeks, Water Hyacinth regrowth will significantly decrease (Owens and Madsen 1995).*
- *This species seeds can remain viable for up to 5-20 years (FAO 2013).*

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5
Yes, but this species has neither been observed in ballast/fouling ships entering the Great	Score x 0.1

Lakes nor in ports in direct trade with the Great Lakes.	
No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0
Unknown	U

Vector Potential Scorecard				
Vector	**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind	**100**	x 1	**100**	High
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.	**100**	x 1	**100**	High
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)	**100**	x 1	**100**	High
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)	**100**	x 0.75	**75**	Moderate
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)	**100**	x 0.75	**75**	Moderate
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling	**0**	x	**0**	Unlikely
Total Unknowns (U)	**0**	**Confidence Level**	High	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

ESTABLISHMENT POTENTIAL RESULTS

Status: **Established in North America, but not including the Great Lakes.**

Eichhornia crassipes **has a moderate probability of establishment if introduced to the Great Lakes (Confidence level: High).**

Eichhornia crassipes has been reported to tolerate salinities of 0-8.8 ppt, with growth rate decreasing with increasing salinity (Rotella and Luken 2012). This species tolerates water temperatures of 5°C for short periods of time (Owens and Madsen 1995) and survives in water temperatures up to 30°C (NSW DPI 2012b). *Eichhornia crassipes* requires abundant nitrogen, phosphorus, and potassium for growth. The abiotic and climatic conditions of the introduced ranges of *E. crassipes* (e.g. Lake St. Clair, Detroit River, New York) are similar to the Great Lakes. Nutrient inputs to the Great Lakes from runoff may provide the necessary nitrogen and phosphorus levels for *E. crassipes* growth. Slow flowing fresh water bodies located in the Great Lakes basin may provide suitable habitats for this species.

Eichhornia crassipes is somewhat likely to be able to overwinter in the Great Lakes basin as rooted plants, which are more resistant to freezing temperatures than free floating mats (Owens and Madsen 1995). There is anecdotal evidence that *E. crassipes* has overwintered in private ponds in Michigan (Ankney 2012). *Eichhornia crassipes* may experience increased mortality and reduced regrowth after long periods of near-freezing temperatures (Adebayo et al. 2011, Owens and Madsen 1995, Rixon et al. 2005). Climate change may make the Great Lakes more suitable for this species' establishment. Shorter ice duration and warmer temperatures may improve this species' ability to survive the winter in the Great Lakes (Adebayo et al. 2011).

It produces seeds that can remain viable for 5-20 years (FAO 2013). Although it is capable of producing dormant seeds, evidence suggests that *E. crassipes* will not establish a population in the Great Lakes region via sexual reproduction due to the lack of genetic diversity of the introduced populations and the lack of seeds found in the sediment where it has been introduced (Adebayo et al. 2011). Its primary method of spread is through vegetative fragmentation (NSW DPI 2012b). This species rapidly grows and can double its biomass every 2 to 34 days (Gutiérrez et al. 2001).

Eichhornia crassipes forms dense stands, which may impact species in the Great Lakes. In San Joaquin Delta, California, insect densities where lower in patches of *E. crassipes* and there was a difference in insect composition between *E. crassipes* and the native pennywort (*Hydrocotyle umbellata*) (Toft 2000). Non-native introduced amphipods such as *Crangonyx floridanus* were more abundant in *E. crassipes* stands than in the native pennywort stands, and are not frequently consumed by fish. Fish preyed heavily on native amphipod *Hyalella azteca* that was more abundant in the native pennywort. It is suggested that the presence of *E. crassipes* may influence native invertebrate community assemblages. In Lake Okeechobee, *E. crassipes* displaced native bulrush and shaded out native submerged plants that provide important habitats for fish, waterfowl, and other animals (UF IFAS 2013). In Caohai and Dianchi lakes in Yunnan province, southwestern China, *E. crassipes* had competed with native plants for water, nutrients, and space, and contributed to the reduction in native plant diversity (Jianqing et al. 2001).

Control methods include mechanical pulling, biological control, and herbicide. The most effective control method is 2,4-D herbicide, which kills *E. crassipes* and reduces the populations of native species to some extent (Ivanov et al. 2007). Surveillance and management efforts are currently underway to detect, control, and/or eradicate this plant in Michigan (MI DEQ 2013) and Wisconsin (Falck et al. 2010).

However, a basin-wide monitoring program is lacking (Dupre 2011). Michigan has a state management plan to prevent aquatic invasive species introductions, limit their dispersal, and control their populations (MI DEQ 2013). The Michigan Department of Natural Resources and the United States Environmental Protection Agency (USEPA) have an early detection and rapid response plant regarding the establishment of *E. crassipes* (Ankney 2012).

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
	5

- *Estimates for the lethal level of salinity for Water Hyacinth range from roughly 2-8 ppt (Rotella and Luken 2012).*
- *If air temperature remains at 5˚C for 2-3 weeks, Water Hyacinth has a significant decrease in regrowth (Owens and Madsen 1995).*
- *Optimum growth of this species occurs at temperatures between 28°C and 30°C, and requires abundant nitrogen, phosphorus, and potassium (NSW DPI 2012b).*
- *Although this plant will tolerate a wide range of growth conditions and climatic extremes including frost, it is rapidly killed by sea strength salinity and will not grow in brackish water (NSW DPI 2012b).*
- *Water Hyacinth seeds can remain viable for up to 5-20 years (FAO 2013).*

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9
Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
	6

- *Water Hyacinth seeds can remain viable for up to 5-20 years (FAO 2013).*

- *Although it is capable of producing dormant seeds, evidence suggests that* E. crassipes *will not establish a population in the Great Lakes region via seeds due to the lack of genetic diversity of the introduced populations and the lack of seeds found in the sediment where it has been introduced (Adebayo et al. 2011).*
- *However, there is anecdotal evidence that* E. crassipes *has overwintered in private ponds in Michigan (Ankney 2012).*
- *Water Hyacinth does not tolerate long exposure to temperatures lower than 0°C. Short-term exposure to temperatures at or below freezing can be tolerated (IPAMS 2013).*
- *It is not known as an overwintering species in Rixon et al. (2005).*
- Eichhornia crassipes *may experience increased mortality and reduced regrowth potential after long periods of near-freezing temperatures (Adebayo et al. 2011, Owens and Madsen 1995, Rixon et al. 2005).*
- *In Dallas, Texas, water hyacinth populations were completely killed during one winter (Owens and Madsen 1995). The winter of 1990-1991 there was a period of 11 days with the minimum air temperature below freezing.*
- *Rooted plants are more resistant to overwintering than floating mats (Owens and Madsen 1995).*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
	0

- *This species is an autotroph.*

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	0
Unknown	U
	9

- Eichhornia crassipes *may form dense, single species stands that often do not provide ideal habitat or food for native wildlife and may limit access to the water for some species. These native wildlife populations may be forced to relocate or perish, ultimately resulting in a loss of biodiversity and a disruption in the balance of the ecosystem (Robinson 2007).*

- *In Lake Okeechobee, water hyacinth displaced native bulrush and shaded out native submerged plants that are important habitat for fish, waterfowl, and other animals. Water hyacinth infestations also interfere with the nesting and feeding habits of the endangered Everglades snail kite, and in extreme cases can push over or uproot emergent vegetation in which kites build their nests (UF IFAS 2013).*
- Eichhornia crassipes *forms dense stands, which may impact species in the Great Lakes. In San Joaquin Delta, California, insect densities where lower in patches of* E. crassipes *and there was a difference in insect composition between* E. crassipes *and the native Pennywort (*Hydrocotyle umbellata*)(Toft 2000). Non-native introduced amphipods such as* Crangonyx floridanus *were more abundant in* E. crassipes *than in the native pennywort, and are not frequently consumed by fish. Fish preyed heavily on native amphipod* Hyalella azteca *that was more abundant in the native Pennywort. It is suggested that the presence of* E. crassipes *may influence native invertebrate community assemblages.*
- *In Caohai and Dianchi lakes in Yunnan province, southwestern China,* E. crassipes *had competed with native plants for water, nutrients, and space, and contributed to the reduction in native plant diversity (Jianqing et al. 2001).*

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
	6

- *This species has a high fecundity (WIDNR 2013).*
- *This species exhibited a biomass doubling time of 2.03-34.66 days (Gutiérrez et al. 2001).*

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
	8

- *Water Hyacinth reproduces largely via clonal growth, though sexual reproduction also may occur with production of seeds but at reduced frequency in introduced, temperate populations (Adebayo et al. 2011).*

- *Although it is capable of producing dormant seeds, evidence suggests that* E. crassipes *is not very likely to establish a population in the Great Lakes region via seeds due to the lack of genetic diversity of the introduced populations and the lack of seeds found in the sediment where it has been introduced in Lake St. Clair and the Detroit River (Adebayo et al. 2011).*
- *This same paper predicts this plant could be introduced into the Great Lakes after disposal of the plant into the St. Clair and the Detroit River and subsequent dispersal (Adebayo et al. 2011).*
- *Since Water Hyacinth reproduces sexually by seeds, the chances are higher of developing a cold-tolerant ecotype than if it reproduced only vegetatively (Washington State Department of Ecology 2013).*
- *This species reproduces by vegetative fragmentation (NSW DPI 2012b), which may aid its establishment, but there is no literature regarding its establishment in the Great Lakes.*

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	6

- *Water Hyacinth grows in still or slow-flowing fresh water in tropical and temperate climates (NSW DPI 2012b).*
- *Water Hyacinth is an aquatic plant native to the warm climate of the Amazon basin in South America (Ankney 2012).*
- *The United States states that have the most similar climatic conditions to where this species is native are New York and Washington; furthermore, it is established in the southern part of New York and the southwestern part of Washington (USDA NRCS 2013).*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	6

- *Water Hyacinth grows in still or slow-flowing fresh water in tropical and temperate climates (NSW DPI 2012b).*

- *Optimum growth of this species occurs at temperatures between 28°C and 30°C, and requires abundant nitrogen, phosphorus, and potassium (NSW DPI 2012b).*
- *Although this plant will tolerate a wide range of growth conditions and climatic extremes including frost, it is rapidly killed by sea strength salinity and will not grow in brackish water (NSW DPI 2012b).*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0
Unknown	U
	8

- *Water Hyacinth grows in still or slow-flowing fresh water (NSW DPI 2012b).*
- *Water Hyacinth is a free-floating perennial water plant that forms large, dense mats on the water surface (NSW DPI 2012b).*
- Eichhornia crassipes *is mainly found in inshore and shallow areas to which it is swept by currents and less often in patchy offshore areas (Osumo 2001).*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0
Unknown	U
	8

- *Water Hyacinth grows in still or slow-flowing fresh water in tropical and temperate climates (NSW DPI 2012b).*
- *Optimum growth of this species occurs at temperatures between 28°C and 30°C (NSW DPI 2012b).*
- *Although this plant will tolerate a wide range of growth conditions and climatic extremes including frost, it is rapidly killed by sea strength salinity and will not grow in brackish water (NSW DPI 2012b).*
- *According to recent climate change models, this species' distribution may expand into higher latitudes as temperatures rise, posing problems to formerly hyacinth-free areas (UNEP GEAS 2013).*

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
	7

- *Water hyacinth is a free-floating perennial water plant that forms large, dense mats on the water surface (NSW DPI 2012b).*
- *This plant requires abundant nitrogen, phosphorus, and potassium (NSW DPI 2012b).*

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Great Lakes and is not likely to be introduced	-80% total points (at end)
Unknown	U
	9

- *There is no critical species required by the species being assessed.*

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of	9

this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes)	6
Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0
Unknown	U
	0

- *There was no record of another species aiding the establishment of this species at the time of this assessment.*

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0
Unknown	U
	0

- *There are no known predators of this plant in the Great Lakes.*

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9
Frequent, moderate inocula	6
Frequent, small inocula OR infrequent, large inocula	3

Infrequent, small or moderate inocula	0
Unknown	U
	6

- *Recolonization ofWater Hyacinth via seeds seems unlikely given the absence of genetic diversity in introduced populations and low seed production in temperate areas (Adebayo et al. 2011).*
- *Fragments of this species are not easily accidentally introduced, but it is often sold and planted (WIDNR 2013).*
- *Vegetative fragmentation is a primary method for this species spreading (WIDNR 2013).*

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
	9

- *This species has established in 24 states within the United States (USDA NRCS 2013).*
- *Water Hyacinth has emerged as a major weed in more than 50 countries (UNEP GEAS 2013).*
- *In the United States, it is found in California (Toft 2000), Michigan (Ankney 2012, Adebayo et al. 2011), Texas (Owens and Madsen 1995), Florida (Ivanov et al. 2007).*
- *This species occurs in southwestern China (Jianqing et al. 2001)*
- *Water Hyacinth occurs in the Guadina River basin in Spain (Téllez et al. 2008).*
- *This species occurs in Australia (NSW DPI 2012b).*
- Eichhornia crassipes *is found in 50 countries on 5 continents (Lowe et al. 2000)*

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
	9

- *Water Hyacinth has been identified by the International Union for Conservation of Nature (IUCN) as one of the 100 most aggressive invasive species and recognized as one of the top 10 worst weeds in the world. It is characterized by rapid growth rates, extensive dispersal capabilities, large and rapid reproductive output, and broad environmental tolerance (UNEP GEAS 2013).*
- *This species rapidly grows and can double its biomass every 2 to 34 days (Gutiérrez et al. 2001).*

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing the establishment and spread of this species)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent the establishment and/or spread of this species	0
Unknown	U
	-30%

- *Surveillance and management efforts are currently underway to detect, control and/or eradicate this plant in Michigan (MI DEQ 2013) and Wisconsin (Falck et al. 2010). However, a basin-wide monitoring program is lacking (Dupre 2011).*
- *Michigan has a state management plan to prevent AIS introductions (e.g. water hyacinth), limit their dispersal, and to manage and control them (MI DEQ 2013). However, this program may have limited long-term impact, as four of the five sites where Water Hyacinth was detected in 2011 were revisited in 2012 and all 4 sites were again positive for water hyacinth, each estimated at the same population levels in 2011 (http://www.michigan.gov/documents/dnr/Water_Hyacinth_in_Michigan_Final_12-6-12_405850_7.pdf).*
- *The USEPA and Michigan Department of Natural Resources has an early detection and rapid response plan in place to protect the state from establishment of Water Hyacinth (MIDNR 2013).*
- *Control methods include mechanical pulling, biological control, and herbicide. The most effective control method is 2,4-D herbicide, which kills* E. crassipes *but reduces the populations of native species to some extent (Ivanov et al. 2007).*

Establishment Potential Scorecard				
Points	**Probability for Establishment**	A. Total Points (pre-adjustment)		102
>100	High	**Adjustments**		
		B. Critical species	A*(1 - 0%)	102
51-99	Moderate	C. Natural enemy	B*(1 - 0%)	102
		Control measures	C*(1 - 30%)	71.4
0-50	Low	**Potential for Establishment**		Moderate

# of questions answered as “unable to determine”	Confidence Level		
0-1	High	Total # of questions unknown	0
2-5	Moderate		
6-9	Low	Confidence Level	High
>9	Very low		

Section C: Potential for Impact

<u>IMPACT POTENTIAL RESULTS</u>

Environmental: High

Socio-Economic: High

Beneficial: Moderate

***Eichhornia crassipes* has the potential for high environmental impact if introduced to the Great Lakes.**

Eichhornia crassipes grows in thick mats that reduce the light and oxygen availability in the water (Ivanov et al. 2007). After removing *E. crassipes* from Lake Victoria by cutting, there was a significant increase in dissolved oxygen (Osumo 2001). In Africa, *Eichhornia crassipes* can be detrimental to water availability due to its high rate of evapotranspiration and its ability to take advantage of scarce water reserves, resulting in an annual loss of 7 billion m^3 of water from the Nile River (DeGroot 1993, Padilla and Williams 2004). In China, *E. crassipes* has exacerbated water pollution by absorbing heavy metals and releasing them at death (Jianqing et al. 2001).

In Lake Okeechobee, *E. crassipes* displaced native bulrush and shaded out native submerged plants that provide important habitats for fish, waterfowl, and other animals (UF IFAS 2013). In Caohai and Dianchi lakes in Yunnan province, southwestern China, *E. crassipes* competed with native plants for water, nutrients, and space, and contributed to the reduction in native plant diversity (Jianqing et al. 2001).

Eichhornia crassipes can potentially alter predator-prey relationships. In San Joaquin Delta, California, insect densities where lower in patches of *E. crassipes* and there was a difference in insect composition between *E. crassipes* and the native pennywort (*Hydrocotyle umbellata*) (Toft 2000). Non-native introduced amphipods such as *Crangonyx floridanus* were more abundant in *E. crassipes* than in the native pennywort, and are not frequently consumed by fish. Fish preyed heavily on native amphipod *Hyalella azteca* that was more abundant in the native pennywort. It is suggested that the presence of *E. crassipes* may influence native invertebrate community assemblages.

***Eichhornia crassipes* has the potential for high socio-economic impact if introduced to the Great Lakes.**

Eichhornia crassipes can pose a risk to human health by providing a habitat for mosquitos, and may increase the risk of mosquito-borne diseases (Jianqing et al. 2001, Mailu 2001). This species has reduced water availability in Lake Victoria basin, which led to social conflicts over the lack of clean water (Mailu 2001). In addition, the infestation of *E. crassipes* resulted in increased transportation costs, blockage of irrigation canals, and difficulties in electricity and water extraction. Due to *E. crassipes* infestation, the Kenyan port of Kisumu reported a 70% decline in economic activities. This species can impact recreational fishing by making it difficult to access fishing grounds and preventing boating (Mailu 2001, Richardson and van Wilgen 2004).

In Benin, the infestation of *E. crassipes* was estimated to significantly reduce the annual income of the villagers, who relied on fishing and trade for an income (De Groote et al. 2003). Biological control of the infested waters in Benin was estimated to be United States $2.09 million.

***Eichhornia crassipes* has the potential for moderate beneficial impact if introduced to the Great Lakes.**

Eichhornia crassipes is an ornamental plant used in water gardens. *Eichhornia crassipes* has the potential to be used for bioethanol and biogas production, electricity generation, industrial uses, animal feed, or agriculture (Jafari 2010, Malik 2007). It may be utilized for wastewater treatment or heavy metal remediation (Pinto et al. 1987).

POTENTIAL ENVIRONMENTAL IMPACT

NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1 √
Not significantly	0
Unknown	U

- *Phytoplankton productivity was reduced when Water Hyacinth water present in Lake Naivasha (Kenya), which suggests it may alter species composition and biodiversity (Mironga 2006).*
- *In China,* E. crassipes *has exacerbated water pollution by absorbing heavy metals and releasing them at death (Jianqing et al. 2001).*

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6 √
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival,	1

fecundity) or decline of at least one native population	
Not significantly	0
Unknown	U

- Eichhornia crassipes *may form dense single species stands that often do not provide ideal habitat or food for native wildlife and may limit access to the water for some species. These native wildlife populations may be forced to relocate or perish, ultimately resulting in a loss of biodiversity and a disruption in the balance of the ecosystem (Robinson 2007).*
- *Dense floating rafts of* Eichhornia crassipes *can form on the water's surface, restricting light to the complete exclusion of other native plants, and decreasing the air exchange between the water's surface and the atmosphere (Robinson 2007).*
- *Dense mats of* Eichhornia crassipes *can lower dissolved oxygen levels in water bodies, leading to reduction of aquatic fish production (Shanab et al. 2010).*
- *Water Hyacinth is very efficient in taking up calcium, magnesium, sulfur, ferric iron, manganese, aluminum, boron, copper, molybdenum, zinc, nitrogen, phosphorus, and potassium, favoring its growth over other aquatic species (Shanab et al. 2010).*
- Eichhornia crassipes *is an invasive weed known to out-compete native plants and negatively affect microbes, including phytoplankton (Shanab et al. 2010).*
- *In 1994, about 10 km^2 of Dianchi Lake in the Yunnan Province of China was completely covered by dense mats of* Eichhornia crassipes*. The rapid spread of this weed has resulted in declines in native aquatic plants and threats to local biodiversity (Yan et al. 2001).*
- *In Lake Okeechobee, water hyacinth displaced native bulrush and shaded out native submersed plants that are important habitat for fish, waterfowl, and other animals. Water hyacinth infestations also interfere with the nesting and feeding habits of the endangered Everglades snail kite, and in extreme cases can push over or uproot emergent vegetation in which kites build their nests (UF IFAS 2013).*

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in the food web)	6
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	1 √
Not significantly	0
Unknown	U

- Eichhornia crassipes *forms dense monocultures that can threaten local native species diversity and change the physical and chemical aquatic environment, thus altering ecosystem structure and function by disrupting food chains and nutrient cycling (Shanab et al. 2010).*
- *Algae, a major component of the base of the food chain, can be shaded out by dense mats of* Eichhornia crassipes*. The resulting decline in algae can disrupt the entire food web in a water body (Robinson 2007).*
- Eichhornia crassipes *can potentially alter predator-prey relationships. In San Joaquin Delta, California, insect densities where lower in patches of* E. crassipes *and there was a difference in insect composition between* E. crassipes *and the native pennywort (*Hydrocotyle umbellata*)(Toft 2000). Non-native introduced amphipods such as* Crangonyx floridanus *were more abundant in* E. crassipes *than in the native Pennywort, and are not frequently consumed by fish. Fish preyed heavily on native amphipod* Hyalella azteca *that was more abundant in the native pennywort. It is suggested that the presence of* E. crassipes *may influence native invertebrate community assemblages.*

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0
Unknown	U √

- *There were no recorded incidences of genetic effects found at the time of this assessment.*

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6 √
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1
Not significantly	0
Unknown	U

- Eichhornia crassipes *forms dense monocultures that can threaten local native species diversity and change the physical and chemical aquatic environment, thus altering ecosystem structure and function by disrupting food chains and nutrient cycling (Shanab et al. 2010).*
- *Dense mats of* Eichhornia crassipes *can lower dissolved oxygen levels in water bodies leading to reduction of aquatic fish production (Shanab et al. 2010).*
- *Dense floating rafts of Water Hyacinth can form on the water's surface, restricting light to the complete exclusion of other native plants, and decreasing the air exchange between the water's surface and the atmosphere (Robinson 2007).*
- *Water Hyacinth is very efficient in taking up calcium, magnesium, sulfur, ferric iron, manganese, aluminum, boron, copper, molybdenum, zinc, nitrogen, phosphorus, and potassium (Shanab et al. 2010).*
- *Eutrophic conditions arise when this plant dies and decomposes due to the large release of nutrients the plant takes in (Shanab et al. 2010).*
- *After removing* E. crassipes *by cutting, there was a significant increase in dissolved oxygen (Osumo 2001).*

E6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1 √
Not significantly	0
Unknown	U

- Eichhornia crassipes *is known to out-compete native plants and negatively affect microbes, including phytoplankton (Shanab et al. 2010).*
- *Sediment levels increase with increasing* E. crassipes *abundance (Robinson 2007).*
- Eichhornia crassipes *may displace or shade out native macrophytes, thus altering macrophyte communities.*

Environmental Impact Total	**15**
Total Unknowns (U)	**1**

Scoring		
Score	# U	**Impact**
>5	Any	**<u>High</u>**
2-5	Any	Moderate
0	0-1	Low
1	0	
0	≥2	Unknown
1	≥1	

POTENTIAL SOCIO-ECONOMIC IMPACT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6 √
Yes, but negative consequences have not been widespread, long lasting, or severe	1
Not significantly	0
Unknown	U

- *Its vigorous growth and invasive characteristics have created nuisance problems for water quality, mosquito control, and water-borne transportation (Owens and Madsen1995).*
- *Floating mats of* Eichhornia crassipes *support organisms that are detrimental to human health. The ability of its mass of fibrous, free-floating roots and semi-submerged leaves and stems to decrease water currents increases breeding habitat for the malaria causing anopheles mosquito as evidenced in Lake Victoria (UNEP GEAS 2013).*
- *Mansonioides mosquitoes, the vectors of human lymphatic filariasis causing nematode* Brugia*, breed on this weed (UNEP GEAS 2013).*
- *Snails serving as vector for the parasite of schistosomiasis (*Bilharzia*) reside in the tangled weed mat (UNEP GEAS 2013).*
- Eichhornia crassipes *has also been implicated in harboring the causative agent for cholera (UNEP GEAS 2013).*

- *At the local level, increased incidences of crocodile attacks have been attributed to the heavy infestation of the weed, which provides cover to these reptiles, as well as to poisonous snakes (UNEP GEAS 2013).*
- Eichhornia crassipes *can pose a risk to human health by providing a habitat for mosquitos, and may increase the risk of mosquito-borne diseases (Jianqing et al. 2001, Mailu 2001).*

S2) Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1 √
Not significantly	0
Unknown	U

- *The large, dense monoculture formed by this species covers lakes and rivers, blocking waterways and interfering with the water transport of agriculture products, tourism activities, water power, and irrigation of agricultural fields (Shanab et al. 2010).*
- *The overall economic impacts of the weed in seven African countries have been estimated at between US$20-50 million every year. Across Africa costs may be as much as $100 million annually (UNEP GEAS 2013).*
- *The infestation of* E. crassipes *resulted in increased transportation costs, blockage of irrigation canals, and difficulties in electricity and water extraction (Mailu 2001).*

S3) Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1 √
Not significantly	0
Unknown	U

- *Its vigorous growth and invasive characteristics have created nuisance problems for water quality, mosquito control, and water-borne transportation (Owens and Madsen 1995).*
- *The overall economic impacts of the weed in seven African countries have been estimated at between US$20-50 million every year. Across Africa costs may be as much as $100 million annually (UNEP GEAS 2013).*

S4) Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6 √
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0
Unknown	U

- *The large, dense monoculture formed by this species covers lakes and rivers, blocking waterways and interfering with the water transport of agriculture products, water power, and irrigation of agricultural fields (Shanab et al. 2010).*
- *The overall economic impacts of the weed in seven African countries have been estimated at between US$20-50 million every year. Across Africa costs may be as much as $100 million annually (UNEP GEAS 2013).*
- *In Benin, the infestation of* E. crassipes *was estimated to reduce the annual income of the villagers by US$84 million, who relied on fishing and trade for an income (De Groote et al. 2003). Biological control for the infested waters in Benin were estimated to be United States $2.09 million.*

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6 √
Yes, but negative consequences have been small	1
Not significantly	0
Unknown	U

- *The large, dense monoculture formed by this species covers lakes and rivers, blocking waterways, and interfering with tourism activities (Shanab et al. 2010).*
- *The overall economic impacts of the weed in seven African countries have been estimated at between US$20-50 million every year. Across Africa costs may be as much as $100 million annually (UNEP GEAS 2013).*

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6 √
Yes, but negative consequences have been small	1
Not significantly	0
Unknown	U

- *The large, dense monoculture formed by this species covers lakes and rivers (Shanab et al. 2010).*
- Eichhornia crassipes *can displace native species, reduce biodiversity, limit recreation, diminish aesthetic value, and decrease water quality and flow (Robinson 2007).*

Socio-Economic Impact Total	**26**
Total Unknowns (U)	**0**

Scoring		
Score	# U	**Impact**
>5	Any	<u>**High**</u>
2-5	Any	Moderate
0	0-1	Low
1	0	Low
0	≥2	Unknown
1	≥1	Unknown

POTENTIAL BENEFICIAL EFFECT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular effect. An "Unknown" response is appropriate if the potential for a particular effect might be inferred but has not been explicitly reported or if there is an unresolved debate about a particular effect.

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1
Not significantly	0 √
Unknown	U

- *There was no literature declaring* E. crassipes *was used as a biological control agent for other organisms at the time of this assessment.*

B2) Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?

Yes, it is economically important to at least one of these industries	6
Yes, but its economic contribution is small	1 √
Not significantly	0
Unknown	U

- *This species can be bought from many online retailers (e.g., pondplantsforsale.com).*
- *Retail advertisements also recommend this species as a good oxygenator plants for outdoor ponds (e.g., pondplantsforsale.com).*
- *It is speculated that the biomass can be used in wastewater as substrate for bioethanol and biogas production, electricity generation, industrial uses, animal feed, or agriculture (Jafari 2010, UNEP GEAS 2013).*

B3) Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local communities and/or tourism	6
It is sometimes employed recreationally, but adds little value to local communities or tourism	1 √
Not significantly	0
Unknown	U

- *This species can be used as an attractive pond plant or aquarium decoration.*
- *Retail advertisements also recommend this species as a good oxygenator plants for outdoor ponds (e.g., pondplantsforsale.com).*

B4) Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6

It has some medicinal or research value, but is not of high priority OR It is potentially important to medicine or research and is currently being or scheduled to be studied	1 √
Not significantly	0
Unknown	U

- *It is speculated that the biomass can be used in medicines (UNEP GEAS 2013).*
- *Water Hyacinth has been found to produce an alkaloid that can affect certain bacteria, fungi, and green algae strains; plant compounds exhibited antibacterial activities against both the Gram positive bacteria;* Bacillus subtilis *and* Streptococcus faecalis*; and the Gram negative bacteria;* Escherichia coli *and* Staphylococcus aureus *(Shanab et al. 2010).*

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1 √
Not significantly	0
Unknown	U

- *It is speculated that the biomass can be used in wastewater treatment or heavy metal and dye remediation (Pinto et al. 1987, UNEP GEAS 2013).*

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1
Not significantly	0 √
Unknown	U

Beneficial Effect Total	**4**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	**Moderate**
0	0-1	Low
1	0	
0	≥2	Unknown
1	≥1	

Scientific Name: *Hydrilla verticillata* Royle

Common Name: Hydrilla

Synonyms: Water Thyme

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: High

Hitchhiking/fouling: High

Unauthorized intentional release: Low

Stocking/planting/escape from recreational culture: Unknown

Escape from commercial culture: Unknown

Transoceanic shipping: Unlikely

***Hydrilla verticillata* has a high probability of introduction to the Great Lakes (Confidence level: Moderate).**

Potential pathway(s) of introduction: Dispersal, Hitchhiking/Fouling, Unauthorized Intentional Release, Escape from Recreational and Commercial Culture

This species occurs near the Great Lakes basin. It occurs in Lake Manitou, Indiana (D. Keller, Indiana DNR, pers. comm. 2006), has been reported in private ponds in 2007 in Marinette County, Wisconsin (WIDNR 2009), and has been reported in Tonawanda Creek of the New York State Erie Canal System in 2012 (NY DEC 2012). *Hydrilla verticillata* was first introduced to the United States as an aquarium plant in the 1960s and since has spread through recreational activities (Langeland 1996). *Hydrilla verticillata* spreads through vegetative fragmentation (GISD 2006a). *Hydrilla verticillata* can potentially enter the Great Lakes region through fragmentation and subsequent dispersal from its current range. *Hydrilla verticillata* can be dispersed by plant fragments attached to boats or trailers, or tubers that are consumed and excreted by waterfowl (GISD 2006a).

This species is prohibited in the Great Lakes including Chicago, Illinois, Indiana, Michigan, and Wisconsin. It is not prohibited in New York, Ohio, Ontario, Pennsylvania, or Quebec (GLPANS 2012). *Hydrilla verticillata* is listed on the Federal Noxious Weed List.

This species can be purchased and introduced to the Great Lakes via unauthorized intentional release. Although, *H. verticillata* is listed on the United States Federal Noxious Weed, it is still sold over the internet as an aquarium plant and can be obtained from Ontario's aquarium trade (Marson et al. 2009). Moreover, this species has been found as a contaminant in aquarium orders of other plant species (Maki and Galatowitsch 2004).

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100 √
No, this species does not occur near waters connected to the Great Lakes basin and/or is not mobile or able to be transported by wind or water.	0
Unknown	U

- *This species primarily reproduces vegetatively; as such, small fragments that float downstream can grow into a new plant (PA Sea Grant 2013).*
- Hydrilla verticillata *can spread to new locations through floating debris or on water currents (GISD 2006a). It therefore has the potential to enter the Great Lakes region through fragmentation and dispersal from rivers leading to the basin.*
- *Hydrilla was found in Indiana's Lake Manitou in 2006, prompting closure to public boating access and chemical treatment (D. Keller, Indiana DNR, pers. comm. 2006). As of June of 2008, treatment has significantly reduced hydrilla growth and tuber production, prompting a limited re-opening of one boat ramp (INDNR 2009).*
- *This species was also found in a privately-owned artificial pond in Marinette County, Wisconsin in 2005 (confirmed in 2007; WIDNR 2009).*

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1 √
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25
Unknown	U

- Hydrilla verticillata *is absent in Michigan but has isolated populations in Indiana, Wisconsin, and Ohio (MI DEQ 2013).*
- *The Lake Manitou population in Rochester, IN was found in 2006 and 2008 (USGS NAS 2015). After the first year's treatment, the tuber bank decreased by 86%, and in 2008, the DNR boat ramp access was reopened to the public (http://www.eddmaps.org/distribution/point.cfm?id=2479555).*
- *Hydrilla was detected at the base of a boat ramp on Tonawanda Creek, part of the New York State/Erie Canal System in Tonawanda, NY in September 2012 (http://www.dec.ny.gov/press/85078.html , http://ne-ecological-services.blogspot.com/2012/10/hydrilla-closes-in-on-great-lakes.html). This confirms hydrilla as being within one mile of the Niagara River (and thus the Great Lakes).*
- *Hydrilla was detected in an artificial pond in Marinette County, WI in 2005 and 2007 (USGS NAS 2015). The aquatic herbicide, Aquathol ® K, was applied in August 2007, followed by a fall water drawdown (http://www.eddmaps.org/distribution/point.cfm?id=2480259).*
- *An Ohio population was found in shallow man-made wetlands, West Creek Reservation, Parma, Cuyahoga County in 2011 (http://www.eddmaps.org/distribution/point.cfm?id=2277127)*

- *Furthermore, monoecious hydrilla occurs in thin patches along much of the Ohio region of the Ohio River to depths of four feet and has been proposed to be a significant source population to the surrounding area (Hydrilla Workshop 2012).*

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100 √
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0
Unknown	U

- Hydrilla verticillata *can be dispersed by plant fragments attached to boats or trailers, or tubers that are consumed and excreted by waterfowl (GISD 2006a).*
- *It is tolerant of periods of desiccation, with twigs and tubers surviving 16 hours to several days out of water, respectively (Basiouny et al. 1978, Kar and Choudhuri 1982).*
- *Imported to the United States as an aquarium plant, it has since been spread through recreational activities (PA Sea Grant 2013). It has the potential to enter the Great Lakes region through fragmentation and dispersal from rivers leading to the basin, or by unintentional human introductions.*
- *Hydrilla is mainly introduced to new waters as castaway fragments on recreational boats, their motors and trailers, and in live wells. Stem pieces root in the substrate and develop into new colonies, commonly beginning near boat ramps. Once established, boat traffic continues to fragment and spread hydrilla throughout the waterbody. While it propagatse primarily by stem fragmentation, axillary buds (turions) and subterranean tubers are also important. Its tubers are resistant to most control techniques (Schardt 1994) and may be viable as a source of reinfestation for years (Van and Steward 1990).*

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1 √
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1
Unknown	U

- *Hydrilla was detected at the base of a boat ramp on Tonawanda Creek, part of the New York State/Erie Canal System in Tonawanda, NY in September 2012 (http://www.dec.ny.gov/press/85078.html , http://ne-ecological-services.blogspot.com/2012/10/hydrilla-closes-in-on-great-lakes.html). This confirms hydrilla as being within one mile of the Niagara River (and thus the Great Lakes). Previously, hydrilla was found in the Cayuga Inlet in New York (http://www.seagrant.sunysb.edu/articles/t/nysg-partners-for-treatment-of-invasive-hydrilla-plant-in-cayuga-inlet-aquatic-invasive-species-news), where it was subsequently treated.*
- *Monoecious hydrilla occurs in thin patches along much of the Ohio region of the Ohio River to depths of four feet and has been proposed to be a significant source population to the surrounding area through bass tournament fishing (Hydrilla Workshop 2012).*

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a) Is this species sold at aquarium/pet/garden stores ("brick & mortar" or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100 √
No, this species this species is rarely/never sold.	0
Unknown	U

- *Although* Hydrilla verticillata *is on the United States Federal Noxious Weed List, it is still sold over the internet as an aquarium plant, leading to a potential means of introduction (GISD 2006a).*
- Hydrilla verticillata *can spread to new locations as an unknown contaminant among other water garden plants (e.g., found in water lily shipments) and through the pet/aquarium trade (GISD 2006a).*
- *Hydrilla has the potential to enter the Great Lakes region by unintentional human introductions. It has been received as a contaminant in orders of other aquarium plants in Minnesota (Maki and Galatowitsch 2004).*
- *Hydrilla is present in Ontario's aquarium trade (Marson et al. 2009).*

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1 √
Unknown	U

- Hydrilla verticillata *is on the United States Federal Noxious Weed List, which makes it illegal in the United States to import or transport between states without a permit, but it is still sold as an aquarium plant over the internet (GISD 2006a).*
- *This species is prohibited in Michigan, meaning it cannot be sold or grown without a permit (http://www.legislature.mi.gov/(S(4y3p5eyuypll2z55banpqd55))/mileg.aspx?page=getObject&objectName=mcl-324-41301).*
- *In Indiana, it is illegal to possess, sell, offer for sale, gift, barter, exchange, or distribute hydrilla (http://www.in.gov/legislative/iac/T03120/A00180.PDF).*
- *It is also prohibited in Minnesota (https://www.revisor.mn.gov/rules/?id=6216.0250) and Wisconsin (http://docs.legis.wisconsin.gov/code/admin_code/nr/001/40.pdf).*
- *An internet search at the time of assessment revealed that "hydrilla" does not appear to be sold by Carolina Biological Supply, online pet stores, or online aquarium stores (at least under that name).*

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0

Unknown	U √

- *Hydrilla may be unknowingly transplanted into private ponds as a contaminant on water garden plants (e.g., water lily shipments). It is often found spreading after extensive 2,4-D herbicide use in public waters once heavily populated with Eurasian water-milfoil (*Myriophyllum spicatum*) (Bates and Smith 1994).*

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is likely to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces), this activity may occur within 20 km of the basin because of the species' popularity/value.	Score x 0.25
Unknown	U √

- Hydrilla verticillata *is on the United States Federal Noxious Weed List, which makes it illegal in the United States to import or transport between states without a permit, but it is still sold as an aquarium plant over the internet (GISD 2006a).*
- *This species is prohibited in Michigan, meaning it cannot be sold or grown without a permit (http://www.legislature.mi.gov/(S(4y3p5eyuypll2z55banpqd55))/mileg.aspx?page=getObject&objectName=mcl-324-41301).*
- *In Indiana and Illinois, it is illegal to possess, sell, offer for sale, gift, barter, exchange, or distribute hydrilla (http://www.in.gov/legislative/iac/T03120/A00180.PDF, http://www.dnr.illinois.gov/adrules/documents/17-805.pdf).*
- *It is also prohibited in Minnesota (https://www.revisor.mn.gov/rules/?id=6216.0250) and Wisconsin (http://docs.legis.wisconsin.gov/code/admin_code/nr/001/40.pdf).*
- *An internet search at the time of assessment revealed that "hydrilla" does not appear to be sold by Carolina Biological Supply, online pet stores, or online aquarium stores (at least under that name).*

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100
No, this species is not commercially cultured in or transported through the Great Lakes region.	0
Unknown	U √

- *Commercial culture or transport of hydrilla in the Great Lakes region is prohibited in Michigan, Illinois, Indiana, Minnesota, and Wisconsin but may be occurring in other states of provinces.*

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes	Score x 0.75

tributaries or connecting waters, or within 20 km of the Great Lakes basin.	
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U √

- Hydrilla verticillata *is on the United States Federal Noxious Weed List, which makes it illegal in the United States to import or transport between states without a permit, but it is still sold as an aquarium plant over the internet (GISD 2006a).*
- *This species is prohibited in Michigan, meaning it cannot be sold or grown without a permit (http://www.legislature.mi.gov/(S(4y3p5eyuypll2z55banpqd55))/mileg.aspx?page=getObject&objectName=mcl-324-41301).*
- *In Indiana and Illinois, it is illegal to possess, sell, offer for sale, gift, barter, exchange, or distribute hydrilla (http://www.in.gov/legislative/iac/T03120/A00180.PDF, http://www.dnr.illinois.gov/adrules/documents/17-805.pdf).*
- *It is also prohibited in Minnesota (https://www.revisor.mn.gov/rules/?id=6216.0250) and Wisconsin (http://docs.legis.wisconsin.gov/code/admin_code/nr/001/40.pdf).*
- *An internet search at the time of assessment revealed that "hydrilla" does not appear to be sold by Carolina Biological Supply, online pet stores, or online aquarium stores (at least under that name).*

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40
No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0 √
Unknown	U

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5
Yes, but this species has neither been observed in ballast/fouling ships entering the Great	Score x 0.1

Lakes nor in ports in direct trade with the Great Lakes.	
No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0
Unknown	U

Vector Potential Scorecard				
Vector	**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind	**100**	x 1	**100**	High
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.	**100**	x 1	**100**	High
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)	**100**	x 0.1	**10**	Low
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)	**U**	x U	**U**	Unknown
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)	**U**	x U	**U**	Unknown
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling	**0**	x	**0**	Unlikely
Total Unknowns (U)	**2**	**Confidence Level**	Moderate	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

ESTABLISHMENT POTENTIAL RESULTS

Status: **Established in North America, but not including the Great Lakes.**

***Hydrilla verticillata* has a moderate probability of establishment if introduced to the Great Lakes (Confidence level: High).**

Hydrilla verticillata has physiological tolerances and adaptive attributes that make it the "perfect aquatic weed" (Langeland 1996). *Hydrilla verticillata* can survive fresh and brackish waters (0-7 ppt salinity) (Langeland 1996). This species can grow in ogliotrophic to eutrophic conditions and in low-light levels (Ramey 2001). It is likely that the Great Lakes has appropriate light and nutrient levels for *H. verticillata*. It is possible that *Hydrilla verticillata* can overwinter in the Great Lakes. It is somewhat winter-hardy (Ramey 2001), and produces turions, which are overwintering vegetative propagules (Maki and Galatowitsch 2004). This species occurs on every continent except Antarctica. It occurs in inland waters near the Great Lakes region such the Erie Canal in New York (NY DEC 2012), which has similar climatic and abiotic conditions as the Great Lakes region. This species inhabits fresh waters at depths up to 15 m (Langeland 1996); such habitats are available in the Great Lakes. The predicted effects of climate change in the Great Lakes may benefit *H. verticillata*. Increased carbon dioxide levels and elevated water temperatures may increase the growth rate of *H. verticillata* (Chen et al. 1994). Climate change may enhance its northward spread (Cooke et al. 2005).

Hydrilla verticillata has a high rate of productivity. It can produce an average of 6,046 tubers per season (Sutton et al. 1992). Experiments show that *H. verticillata* can produce up to 46 axillary tubers per g dry weight (Thullen 1990). Small amounts of *Hydrilla verticillata* can be moved and develop into new populations. About 50% of the fragments with a single whorl can sprout to form a new plant, while those with a greater number of whorls have a higher chance of sprouting (Langeland and Sutton 1980). Its ability for vegetative fragmentation may aid its establishment in new environments. It spreads especially quickly in fast flowing waters, as it efficiently disperses fragments (Ramey 2001).

This species may negatively impact other species. It has high allelopathy potential and has inhibited the growth of lettuce seedlings and duckweed in experiments (Elakovich and Wooten 1989). This species forms dense mats on the surface water, limiting light penetration and light availability for other aquatic plant species (Carlson et al. 2008). *Hydrilla verticillata* is known to be highly adaptive and competitive for light and nutrients (Langeland 1996). It can compete with native plants such as pondweeds (*Potamogeton* sp.) and eelgrass (*Vallisneria americana*).

Surveillance and management efforts are currently underway to detect, control, and/or eradicate this species in Michigan (MI DEQ 2013) and Wisconsin (Falck et al. 2010). However, a basin-wide program is lacking (Dupre 2011). Control of *Hydrilla verticillata* has been attempted with the introduction of Grass Carp, herbicide application, and biocontrol using weevils *Bagous affinis* and *B. hydrillae* (Cooke et al. 2005). Two biocontrol agents, *Bagous affinis* and *B. hydrillae*, were released in Florida in 1987 and 1991, respectively, but both species were unsuccessful in controlling Hydrilla infestation.

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
	6

- Hydrilla verticillata *can grow in almost any freshwater including marshes, springs, lakes, ditches, rivers and tidal zones, and can also tolerate up to 7% salinity.*
- *It can grow in oligotrophic to eutrophic conditions.*
- *It is somewhat winter-hardy, with an optimum growth temperature of 20-27°C (68-81°F) and a maximum temperature of 30°C (86°F) (Kasselmann 1995). In the south it is a perennial, in the north a re-sprouting annual.*
- *It grows at down to 1% full sunlight, and has a low light compensation and saturation point, which can help it grow in low light before other plants do (Van et al. 1976, Bowes et al. 1977).*

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9
Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
	6

- *It is somewhat winter-hardy, with an optimum growth temperature of 20-27°C (68-81°F) and a maximum temperature of 30°C (86°F) (Kasselmann 1995). In the south it is a perennial, in the north a re-sprouting annual.*
- Hydrilla verticillata *produced turions (overwintering vegetative propagule) (Maki and Galatowitsch 2004).*
- *Draining is not sufficient control unless frozen several inches into the mud to kill the turions (tubers).*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U

0

- *This speceis is an autotroph*

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	0
Unknown	U
	9

- *In experiments by Elakovich and Wooten (1989) extracts of hydrilla exhibit high allelopathy potential and inhibited the growth of lettuce seedling and duckweed.*
- *Hydrilla forms a dense mat of vegetation at the water surface and limits light penetration degrading or eliminating all layers below (Bossard et al. 2000).*
- *Hydrilla is highly adaptive to the environment and competitive with most other aquatic plants (Haller and Sutton 1975). It is able to outcompete native submerged plants for light and nutrients. The growth habit of hydrilla enables it to compete effectively for sunlight. It can elongate up to 1 inch per day, and produces the majority of the stems in the upper 2–3 feet of water (Haller and Sutton 1975). This mat of vegetation intercepts sunlight and leads to exclusion of other aquatic plants. Hydrilla is also adapted to use low light levels for photosynthesis (Barko and Smart 1981, Van et al. 1976). Hydrilla efficiently uses a limited supply of nutrients such as carbon, nitrogen, and phosphorus.*

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
	6

- *One plant can produce an average of 6,046 tubers per season (Sutton et al. 1992). An experiment by Thullen (1990) showed that hydrilla can produced up to 46 axillary turions per 1.0 g dry weight (estimated of 2803 turions per m3). About 50% of the fragments with a single whorl can sprout and form new plant, and more than 50% of the fragments with three whorls can sprout (Langeland and Sutton 1980).*

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
	8

- Hydrilla verticillata *reproduces asexually—mostly by vegetative fragmentation, but also from tubers—and sexually (when plants are either monoecious or dioecious with both plants present). It spreads especially fast in flowing water, since it efficiently disperses fragments (GISD 2006a, Ramey 2001).*
- *It also can reproduce through fragmentation, turions (buds that form in leaf axils), and subterranean turions (commonly called "tubers" (IISG n.d.).*
- *Only female plants exist in the United States, while only male plants exist in New Zealand (GISD 2006a).*

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- *This species is native to Asia, Northern Australia; it is a dioecious plant native to India, monoecious in South Korea*
- *This species is found on every continent except Antarctica. It grows up to 50° North latitude in Russia.*
- *It was introduced in Florida in the 1950s, and fully established in the 1970s.*
- *The known United States range for this species is: Alabama, Arizona, California, Connecticut, District of Columbia, Delaware, Florida, Georgia, Indiana, Louisiana, Maryland, Maine, Mississippi, New York, North Carolina, Ohio, Pennsylvania, South Carolina, Tennessee, Texas, Virginia, Washington, Wisconsin.*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	8

- *This species ccurs in slow-moving water of lakes, ponds, streams and rivers; tolerates a wide range of water quality (MI DEQ 2012).*
- *Hydrilla tolerates a wide range of nutrient and pH levels, and persists in low sunlight (IISG n.d.).*
- Hydrilla verticillata *can grow in almost any freshwater including marshes, springs, lakes, ditches, rivers and tidal zones, and can also tolerate up to 7% salinity.*
- *It can grow in oligotrophic to eutrophic conditions.*
- *It is somewhat winter-hardy, with an optimum growth temperature of 20-27°C (68-81°F) and a maximum temperature of 30°C (86°F) (Kasselmann 1995). In the south it is a perennial, in the north a re-sprouting annual.*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0
Unknown	U
	8

- *It grows at down to 1% full sunlight, and has a low light compensation and saturation point, which can help it grow in low light before other plants do (Van et al. 1976, Bowes et al. 1977).*
- *This species grows at depths of up to 6 m (20 ft) (MI DEQ 2012).*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6

Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0
Unknown	U
	9

- *Chen et al. (1994) found that increased carbon dioxide may cause the invasive aquatic plant dioecious hydrilla (*Hydrilla verticillata*) to increase its growth rate at elevated temperatures (e.g., maximum effects of temperature on growth were recorded at 25°C). Thus, as temperatures and carbon dioxide levels rise, hydrilla has the potential to spread more rapidly within and outside of its current range (USEPA 2008).*

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is modersate to high)	3
Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
	9

- *Hydrilla is highly adaptive to the environment and competitive with most other aquatic plants (Haller and Sutton 1975). It is able to outcompete native submerged plants for light and nutrients. The growth habit of hydrilla enables it to compete effectively for sunlight. It can elongate up to 1 inch per day, and produces the majority of the stems in the upper 2–3 feet of water (Haller and Sutton 1975). This mat of vegetation intercepts sunlight and leads to exclusion of other aquatic plants. Hydrilla is also adapted to use low light levels for photosynthesis (Barko and Smart 1981, Van et al. 1976). Hydrilla efficiently uses a limited supply of nutrients such as carbon, nitrogen, and phosphorus.*

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for	3

the species being assessed	
Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Great Lakes and is not likely to be introduced	-80% total points (at end)
Unknown	U
	9

- *There are no critical speciesfor Hydrilla.*

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes)	6
Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0
Unknown	U
	0

- *There is no facilitation needed by this species.*

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)

Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0
Unknown	U
	0

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9
Frequent, moderate inocula	6
Frequent, small inocula OR infrequent, large inocula	3
Infrequent, small or moderate inocula	0
Unknown	U
	3

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
	9

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0

Unknown	U
	9

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing the establishment and spread of this species)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent the establishment and/or spread of this species	0
Unknown	U
	-30%

- *Surveillance and management efforts are currently underway to detect, control and/or eradicate this plant in Michigan (MI DEQ 2013) and Wisconsin (Falck et al. 2010). However, a basin-wide monitoring program is lacking (Dupre 2011).*

Establishment Potential Scorecard				
Points	**Probability for Establishment**	A. Total Points (pre-adjustment)		107
>100	High	**Adjustments**		
		B. Critical species	A*(1- 0%)	107
51-99	Moderate	C. Natural enemy	B*(1- 0%)	107
		Control measures	C*(1- 30%)	74.9
0-50	Low	**Potential for Establishment**		Moderate
# of questions answered as "unable to determine"	**Confidence Level**			
0-1	High	Total # of questions unknown		0
2-5	Moderate			
6-9	Low	Confidence Level		High
>9	Very low			

Section C: Potential for Impact

IMPACT POTENTIAL RESULTS

Environmental: High

Socio-Economic: High

Beneficial: Moderate

***Hydrilla verticillata* has the potential for high environmental impact if introduced to the Great Lakes.**

Hydrilla verticillata can potentially be detrimental to native species and the ecosystem. This species grows aggressively and competitively as dense mats that can displace or shade out native submersed plants. In the southeast United States, *H. verticillata* effectively displaces beneficial native vegetation, such ponweeds (*Potamogeton* sp.) (Langeland 1996), eelgrass (*Vallisneria americana*), and coontail (*Ceratophyllum demersum*) (Rizzo et al. 1996, Van Dijk 1985). The frequency of occurrence of southern naiad in Florida was reduced from 56% to 4% after the establishment of *H. verticillata* (Estes et al. 1990). Infestations may reduce seed production of native aquatic plants, which may reduce the number of native species in the community (De Winton and Clayton 1996). Infestations of this species may shift phytoplankton compositions and alter chlorophyll content (Schmitz et al. 1993). Experimental evidence suggests that *H. verticillata* has high allelopathy potential and can inhibit the growth of lettuce seedling and duckweed (Elakovich and Wooten 1989).

Infestations of *H. verticillata* may alter water chemistry, decrease oxygen levels, increase pH, and increase water temperature (Woodward and Quinn 2011). Non-normal stratification of the water column (Rizzo et al. 1996, Schmitz et al. 1993), decreased oxygen levels (Pesacreta 1988), and fish kills (Rizzo et al. 1996) have been documented in *H. verticillata* infestations.

Sportfish exhibited lower weight and size when *H. verticillata* occupied the majority of the water column, which suggests that foraging efficiency was reduced as open water space and natural vegetation gradients were lost (Colle and Shireman 1980).

***Hydrilla verticilla* has the potential for high socio-economic impact if introduced to the Great Lakes.**

Hydrilla verticillata is among the worst aquatic plants in the southeastern United States, causing costly damage to irrigation and hydroelectric power projects, and recreation (Cooke et al. 2005). This species causes major impacts on infrastructure. *Hydrilla verticillata* can reduce the flow in drainage canals, which can result in flooding and damage to canal banks and structures (Langeland 1996). This species can clog intake pumps used for irrigation. In 1994-1995, Florida spent $14.5 million controlling Hydrilla (Woodward and Quinn 2011). During September 1989 in South Carolina, heavy rainfall and consequent flood discharge caused large mats of *H. verticillata* to break loose and clog intake screens, shutting down two hydroelectric turbines at Guntersville Dam (North Carolina Agricultural Extension Service 1992). This species is a nuisance for navigation of recreational and commercial waters and interferes with swimming (Langeland 1996). The economic value of Orange Lake, Florida ($11 million) was lost during the infestation of *Hydrilla verticillata* (Milon et al. 1986). The dense mats of *H. verticillata* create stagnant waters that can be used as mosquito breeding habitat (Hartis 2013), making this species a risk for human health.

***Hydrilla verticilla* has the potential for moderate beneficial impact if introduced to the Great Lakes.**

Hydrilla verticillata may increase water clarity by reducing sediment re-suspension and reducing phytoplankton populations (Langeland 1996). It is valuable for water gardens and aquariums. *Hydrilla verticillata* may benefit some species as a food source, but only when its coverage is below 30% (Cole and Shireman 1980, Estes et al. 1990).

POTENTIAL ENVIRONMENTAL IMPACT

NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1 √
Not significantly	0
Unknown	U

- *In experiments by Elakovich and Wooten (1989) extracts of hydrilla exhibit high allelopathy potential and inhibited the growth of lettuce seedling and duckweed (Carlson et al. 2008).*

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6 √
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1
Not significantly	0
Unknown	U

- Hydrilla verticillata *is not easy to detect until it fills the lake it infests and tops out at the surface; it grows in thick mats, and shades out or outcompetes ecologically important native submersed plants including* Potamogeton *pondweeds, tapegrass (*Vallisneria americana*), and coontail (*Ceratophyllum demersum*) (Van Dijk 1985).*
- *Hydrilla grows aggressively and competitively, spreading through shallower areas and forming thick mats in surface waters that block sunlight penetration to native plants below (van Dijk 1985).*
- *In the southeast, hydrilla effectively displaces beneficial native vegetation (Bates and Smith 1994) such as wild-celery (*Vallisneria americana*) and coontail (*Ceratophyllum demersum*) (Rizzo et al. 1996, van Dijk 1985)*
- *Colle and Shireman (1980) found sportfish reduced in weight and size when hydrilla occupied the majority of the water column, suggesting that foraging efficiency was reduced as open water space and natural vegetation gradients were lost.*
- *Hydrilla infestations can cause a reduction or the extirpation of populations of native aquatic species (Bossard et al. 2000). Hydrilla may also shift the phytoplankton composition (Canfield et al. 1984). Infestations also*

adversely affect fish populations. Hydrilla may reduce seed production of native species, resulting eventually in a reducing of a number of native species in the community (de Winton and Clayton 1996). A study in Florida found that the frequency of occurrence for the most abundant native submersed plants, coontail and southern naiad decreased from 11% to 4% and 56% to 4%, respectively, from 1987 to 1990 (Ester et al. 1990).

- *Hydrilla forms a dense mat of vegetation at the water surface and limits light penetration degrading or eliminating all layers below (Bossard et al. 2000).*
- *Hydrilla is highly adaptive to the environment and competitive with most other aquatic plants (Haller and Sutton 1975). It is able to outcompete native submerged plants for light and nutrients. The growth habit of hydrilla enables it to compete effectively for sunlight. It can elongate up to 1 inch per day, and produces the majority of the stems in the upper 2–3 feet of water (Haller and Sutton 1975). This mat of vegetation intercepts sunlight and leads to exclusion of other aquatic plants. Hydrilla is also adapted to use low light levels for photosynthesis (Barko and Smart 1981, Van et al. 1976). Hydrilla efficiently uses a limited supply of nutrients such as carbon, nitrogen, and phosphorus.*

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in the food web)	6
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	1
Not significantly	0
Unknown	U √

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0
Unknown	U √

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6 √
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1

Not significantly	0
Unknown	U

- *Dense infestations of this species can alter water chemistry, decrease oxygen levels (Pesacreta 1988, GISD 2006a) and increase pH and water temperature (GISD 2006a).*
- *It has been shown to alter the physical and chemical characteristics of lakes. Stratification of the water column (Schmitz et al. 1993, Rizzo et al. 1996), decreased oxygen levels (Pesacreta 1988), and fish kills (Rizzo et al. 1996) have been documented. Changes in water chemistry may also be implicated in zooplankton and phytoplankton declines (Schmitz and Osborne 1984, Schmitz et al. 1993).*
- *Slow waterflow can also increase the sedimentation rates, water temperature, and pH level (Estes et al. 1990, Joyce et al. 1992) and decrease dissolved oxygen (Bossard et al. 2000). It also affects water nutrient turnover (Bole and Allan 1978, Sinha et al. 2000).*

E6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6 √
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1
Not significantly	0
Unknown	U

- *Hydrilla seriously affects water flow and water use. Infestations in the Mobile Delta are reducing flow in small tidal streams and creating a backwater habitat (J. Zolcynski pers. comm. 1998 in Carlson et al. 2008).*
- *Hydrilla infestations slow the movement of water, causing flooding (Carlson et al. 2008).*
- *Hydrilla forms a dense mat of vegetation at the water surface and limits light penetration degrading or eliminating all layers below (Bossard et al. 2000).*
- *Hydrilla causes severe alterations of plant community composition, community structure, and ecosystem processes in water bodies in California (Bossard et al. 2000). This aquatic weed displaces native plants and adversely impacts freshwater habitats in Florida (Langeland 1996).*

Environmental Impact Total	**19**
Total Unknowns (U)	**2**

Scoring		
Score	# U	**Impact**
>5	Any	<u>**High**</u>
2-5	Any	Moderate
0	0-1	Low
1	0	Low
0	≥2	Unknown

1	≥1	

POTENTIAL SOCIO-ECONOMIC IMPACT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6 √
Yes, but negative consequences have not been widespread, long lasting, or severe	1
Not significantly	0
Unknown	U

- *Some amounts of hydrilla can lead to problems with swimming and wading and have even been linked to drowning deaths in a few cases. As mentioned in previous discussions, hydrilla also creates the perfect stagnant habitat for mosquito breeding. Those itchy bites aren't the worst that can come of this problem, as mosquitoes often carry diseases which can harm us, our pets and our livestock Hartis 2013).*

S2) Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6 √
Yes, but the costs have been small and are largely reparable or preventable	1
Not significantly	0
Unknown	U

- Hydrilla verticillata *slows water flow and clogs irrigation and flood control canals. Florida alone spends millions of dollars for hydrilla "maintenance control" with herbicides and mechanical harvesters; mats of it wash up on shore there, collect at culverts and clog important water control pumping stations (Ramey 2001).*
- *In the TVA system in September 1989, heavy late-season rainfall and consequent flood discharges caused large mats of hydrilla to break loose. These mats clogged intake screens and forced the shutdown of two hydroelectric turbines at Guntersville Dam. Hydrilla mats floated over the spillway and blocked water intakes downstream at Wheeler Dam. The result was $170,000 in lost power plant revenues. Similarly, in June 1991 the St. Stephens hydroelectric plant on Lake Marion in South Carolina was shut down because of a hydrilla accumulation on the water intake screens (http://www.weedscience.ncsu.edu/aquaticweeds/hydrilla.PDF).*

S3) Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0 √
Unknown	U

-

S4) Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6 √
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0
Unknown	U

- *Florida spends roughly $20 million annually to control just one species,* Hydrilla verticillata *(Gordon et al. 2012).*
- *Worldwide economic impacts of* Hydrilla verticillata *include impacts relating to infestation of rice fields, irrigation canals, fishponds and public waterways (Cook and Lüönd 1982) (http://www.sms.si.edu/irlspec/Hydrilla_verticillata.htm).*
- *Hydrilla interferes with a wide variety of commercial operations. Thick mats hinder irrigation operations by reducing flow rates by as much as 90% (CDFA 2000) and impede the operation of irrigation structures (Godfrey et al. 1996). Hydroelectric power generation also is hindered by fragmented plant material that builds up on trash racks and clogs intakes. During 1991, hydrilla at Lake Moultrie, South Carolina shut down the St. Stephen powerhouse operations for seven weeks resulting in $2,650,000 of expenses due to repairs, dredging, and fish loss. In addition, during this repair period, there was an estimated $2,000,000 loss in power generation for the plant (Balciunas et al. 2002).*
- *Boat marinas have been reported closed for extended periods on the Potomac River, Virginia; Lake Okeechobee, Florida; Santee Cooper Reservoirs, South Carolina; and Clear Lake, California (http://dnr.state.il.us/stewardship/cd/biocontrol/7Hydrilla.html).*

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6 √
Yes, but negative consequences have been small	1
Not significantly	0
Unknown	U

- *Hydrilla seriously affects water flow and water use. Its heavy growth commonly obstructs boating, swimming and fishing in lakes and rivers and blocks the withdrawal of water used for power generation and agricultural irrigation.*
- *Hydrilla seriously impedes recreational and commercial boating and prevents swimming and fishing, and major infestations limit weight and size of sport fishes (Colle and Shireman 1980).*
- *Large hydrilla mats prevent access to many of the prime locations used for waterfowl hunting and most warm-water sport fishing. Low oxygen levels in these mats make them unsuitable for the growth and survival of sport fishes and most other aquatic animals. Heavy hydrilla infestations (those that cover more than 25 to 30 percent of the surface in large lakes and impoundments) eliminate fish habitat, cause stunting, and reduce the number of harvestable fish. Thus, hydrilla usually is detrimental to sport fishing over the long term (North Carolina Agricultural Extension Service 1992).*
- *In the late 1980s, hydrilla populations at Lake Guntersville, Alabama increased rapidly. Henderson (1995) examined the economic impact of aquatic plant control programs on recreational use of this lake between 1990 and 1994. He found that the greatest economic value for recreation ($122 million annually) occurred when vegetation levels were 20% of the total lake area, and that revenue declined as hydrilla acreage increased. (Balciunas et al. 2002).*

- *For instance, Florida spends about $14.5 million each year on hydrilla control (Center et al. 1997). Despite this large expenditure, hydrilla infestations in just 2 Florida lakes have prevented their recreational use, causing $10 million annually in losses (Center et al. 1997) (Pimental et al. 2005)*
- *South Carolina's aquatic weed control expenditures grew from less than $50,000 in 1981 to $800,000 in 1989. The Tennessee Valley Authority (TVA) currently spends about $300,000 annually to control hydrilla and has spent more than $1 million since it was discovered in Guntersville Reservoir in 1982. Public agencies in California have spent a total of more than $15 million on hydrilla control since 1976. In Texas, more than $2 million has been expended since 1984 by state and federal agencies for hydrilla control (North Carolina Agricultural Extension Service 1992).*

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6 √
Yes, but negative consequences have been small	1
Not significantly	0
Unknown	U

- *The stagnant water left after the slowing and clogging of rivers, ditches and canals provides prime breeding habitat for mosquitoes (GISD 2006a).*
- *Reducing value of shorefront property (http://www.seagrant.sunysb.edu/ais/pdfs/Hydrilla-brochure030912.pdf).*

Socio-Economic Impact Total	**30**
Total Unknowns (U)	**0**

Scoring		
Score	# U	**Impact**
>5	Any	**<u>High</u>**
2-5	Any	Moderate
0	0-1	Low
1	0	Low
0	≥2	Unknown
1	≥1	Unknown

<u>POTENTIAL BENEFICIAL EFFECT</u>

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular effect. An "Unknown" response is appropriate if the potential for a particular effect might be inferred but has not been explicitly reported or if there is an unresolved debate about a particular effect.

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1
Not significantly	0 √
Unknown	U

B2) Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?

Yes, it is economically important to at least one of these industries	6
Yes, but its economic contribution is small	1 √
Not significantly	0
Unknown	U

- *It is commercially sold for aquaria and water gardens, but limited due to prohibitions in some states.*

B3) Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local communities and/or tourism	6
It is sometimes employed recreationally, but adds little value to local communities or tourism	1 √
Not significantly	0
Unknown	U

- *It is recreationally used for aquaria and water gardens, but limited due to prohibitions in some states.*

B4) Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR It is potentially important to medicine or research and is currently being or scheduled to be studied	1 √
Not significantly	0
Unknown	U

- *Sold as a health product (http://www.swansonvitamins.com/swanson-greenfoods-formulas-wild-crafted-hydrilla-verticillata-500-mg-120-caps?SourceCode=INTL405&CAWELAID=129499578&catargetid=530002460000000567&cagpspn=pla&gclid=CICup7Gew7cCFcU7Mgodtz4ALg)*

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6

Yes, but positive impact for humans or native species is considered negligible	1 √
Not significantly	0
Unknown	U

- *Hydrilla was listed as potentially valuable for use in rhizofiltration (absorbing, concentrating or precipitating compounds from aqueous solutions) (presentation for Bob Grese's Fall 2010 Ecological Restoration class on Phytoremediation)*
- *Highly transparent water is often considered desirable by the public and large populations of submersed aquatic macrophytes, such as hydrilla, will tend to increase water clarity (Canfield et al. 1984). The exact reasons for this increase in water clarity are not completely understood but it probably results from a combination of factors which include lowering sediment re-suspension and reduction of phytoplankton populations by compartmentalizing nutrients. Regardless, large amounts of aquatic macrophytes are necessary to cause substantial increases in water clarity (Canfield et al. 1984, Canfield and Hoyer 1992).*

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1 √
Not significantly	0
Unknown	U

- *Hydrilla provides food supplies for waterfowl in areas with degraded wetlands, such as Florida. Areas with up to 30% cover benefits most fisheries, because it can help grow prey fish populations for game fish to eat (GISD 2006a).*
- *Hydrilla is eaten by waterfowl and fish. Some studies support the view that hydrilla is beneficial as a fishfood and cover (Estes et al. 1990); other researches suggest that fish populations are adversely affected when hydrilla coverage exceeds 30% (Colle and Shireman 1980). Hydrilla appears to be an important habitat for a number of mosquito species (Hearnden and Kay 1997).*
- *Some sport fishermen consider hydrilla to benefit largemouth bass habitat (Tucker 1987). While the opinion that hydrilla is beneficial for sportfish production is supported by certain research (Estes et al. 1990, Porak et al. 1990), other research suggests that largemouth bass are adversely affected when hydrilla coverage exceeds 30% (Colle and Shireman 1980).*
- *Hydrilla is eaten by waterfowl, and maintaining hydrilla populations is sometimes advocated by waterfowl scientists because it increases the feeding habitat for ducks (Johnson and Montalbano 1984, Esler 1989).*

Beneficial Effect Total	**5**
Total Unknowns (U)	**0**

Scoring		
Score	# U	**Impact**
>5	Any	**<u>High</u>**
2-5	Any	Moderate
0	0-1	Low

<table>
<tr><td>1</td><td>0</td><td></td></tr>
<tr><td>0</td><td>≥2</td><td rowspan="2">Unknown</td></tr>
<tr><td>1</td><td>≥1</td></tr>
</table>

Scientific Name: *Hygrophila polysperma*
Robyxb. T. Anders.

Common Name: Indian Hydrographila

Synonyms: East Indian Hygrophila, Indian Swampweed, Miramar Weed, *Hemidelphis polysperma* (Roxb.) Nees, *Justicia polysperma* (Roxb.).

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: Unlikely

Hitchhiking/fouling: Low

Unauthorized intentional release: Moderate

Stocking/planting/escape from recreational culture: Unlikely

Escape from commercial culture: Unlikely

Transoceanic shipping: Unlikely

***Hygrophila polysperma* has a moderate probability of introduction to the Great Lakes (Confidence level: High).**

Potential pathway(s) of introduction: Hitchhiking/Fouling, Unauthorized Intentional Release

Hygrophila polysperma was first introduced into Florida via the aquarium industry in the 1950s (Cuda and Sutton 2000). It was cultivated in Ohio at the end of WWII by an aquarium dealer (Reams 1953), but there is no indication that this species is still cultivated there. This species was introduced to Richmond, Virginia in the 1950s, and established there for 15-20 years until a cold winter caused its population to decline (Nault and Mikulyuk 2009). *Hygrophila polysperma* was first collected in Texas in 1969 in the San Marcos River (Nault and Mikulyuk 2009). This species also occurs in South Carolina (SC DNR 2010). *Hygrophila polysperma* does not currently occur near waters connected to the Great Lakes basin.

Hygrophila polysperma is listed as a Federal Noxious Weed and is prohibited in Illinois and Minnesota (GLPANS 2012), but can be ordered on the internet (Kay and Hoyle 2001). Surveys conducted by Rixon et al. (2005) found that *H. polysperma* was available for purchase in 25% of the pet and aquarium stores surveyed near Lakes Erie and Ontario. Maki and Galatowitsch (2004) had evidence that *H. polysperma* is available for purchase from vendors across the United States with delivery service to Minnesota. In addition, it is sometimes sold under the incorrect name of *Alternanthera sessilis*. The availability of and accessibility to *H. polysperma* in the aquarium industry may increase its potential to be introduced to the Great Lakes; after purchase and usage for aquariums, owners may dispose of the plant into waters connected to the Great Lakes basin.

Hygrophila polysperma spreads via vegetative fragmentation. *Hygrophila polysperma* has a high regrowth potential from stem fragments (Spencer and Bowes 1985). It can get entangled and be transported to the Great Lakes on boats and recreational gear. *Hygrophila polysperma* fragments can also be dispersed by water; however, because this species does not currently occur near waters connected to the Great Lakes basin, it is unlikely that fragments will be transported by water to the Great Lakes.

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100
No, this species does not occur near waters connected to the Great Lakes basin and/or is not mobile or able to be transported by wind or water.	0 √
Unknown	U

- *North American nonindigenous occurrences are limited to Texas, Florida, South Carolina, and Virginia (EDDmapS 2015, USEPA 2008, USGS NAS 2015).*
- Hygrophila polysperma *has brittle stems that fragment, float, and spread on water currents (GISD 2005b, GISD 2005). Rooted nodes of even small fragments are able to grow into new plants (GISD 2005b).*

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25
Unknown	U

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100 √
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0
Unknown	U

- Hygrophila polysperma *spreads naturally by fragmentation (Les 2005) and can get entangled and transported on boats or trailers, or in live wells.*

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1 √
Unknown	U

- *North American nonindigenous occurrences are limited to Texas, Florida, and North Carolina (EDDmapS 2015, USGS NAS 2015).*

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a) Is this species sold at aquarium/pet/garden stores ("brick & mortar" or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100 √
No, this species this species is rarely/never sold.	0
Unknown	U

- *Sale or trade of* H. polysperma *is possible online (e.g.,* Greater Toronto Area aquarium message board*).*
- *According to Rixon et al. (2005), 25% of 20 aquarium stores surveyed between 2002 and 2003 in the Lake Erie region in Michigan and Ontario carried* H. polysperma *in stock.*

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5 √
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1
Unknown	U

- Hygrophila polysperma *is prohibited in Minnesota, making it illegal to possess, import, purchase, propagate, or transport without a permit (*https://www.revisor.mn.gov/rules/?id=6216.0250 *MN Administrative Rules 6216.0230).*
- *In Indiana and Illinois, it is illegal to possess, sell, offer for sale, gift, barter, exchange, or distribute this plant (*http://www.in.gov/legislative/iac/T03120/A00180.PDF*,* http://www.dnr.illinois.gov/adrules/documents/17-805.pdf*).*
- *It is listed as a Federal Noxious Weed under the* Plant Protection Act*, which makes it illegal in the United States to import or transport between States without a permit.*
- *In a study by Maki and Galatowitsch (2004),* H. polysperma *was one of two federal noxious weeds purchased despite its federal status of being illegal to move across state lines.*
- *Moreover, Maki and Galatowitsch (2004) found that this plant may not be labeled with its scientific name or otherwise may be misidentified, as in a case where a vendor was selling* Alternanthera sessilis *as* H. polysperma.

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0 √
Unknown	U

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is likely to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces), this activity may occur within 20 km of the basin because of the species' popularity/value.	Score x 0.25
Unknown	U

- Hygrophila polysperma *is prohibited in Minnesota, making it illegal to possess, import, purchase, propagate, or transport without a permit (https://www.revisor.mn.gov/rules/?id=6216.0250).*
- *In Indiana and Illinois, it is illegal to possess, sell, offer for sale, gift, barter, exchange, or distribute this plant (http://www.in.gov/legislative/iac/T03120/A00180.PDF, http://www.dnr.illinois.gov/adrules/documents/17-805.pdf).*
- *It is listed as a Federal Noxious Weed under the Plant Protection Act, which makes it illegal in the United States to import or transport between States without a permit.*
- *Sale or trade of* H. polysperma *is possible online (e.g., Greater Toronto Area aquarium message board, February 2013 http://gtaaquaria.com/forum/showthread.php?t=42253).*

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100
No, this species is not commercially cultured in or transported through the Great Lakes region.	0 √
Unknown	U

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great	Score x 1

Lakes.	
This activity is unregulated or minimally regulated and is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U

- Hygrophila polysperma *is prohibited in Minnesota, making it illegal to possess, import, purchase, propagate, or transport without a permit (https://www.revisor.mn.gov/rules/?id=6216.0250).*
- *In Indiana and Illinois, it is illegal to possess, sell, offer for sale, gift, barter, exchange, or distribute this plant (http://www.in.gov/legislative/iac/T03120/A00180.PDF, http://www.dnr.illinois.gov/adrules/documents/17-805.pdf).*
- *It is listed as a Federal Noxious Weed under the Plant Protection Act, which makes it illegal in the United States to import or transport between States without a permit.*
- *In a study by Maki and Galatowitsch (2004),* H. polysperma *was one of two federal noxious weeds purchased despite its federal status of being illegal to move across state lines.*
- *Moreover, Maki and Galatowitsch (2004) found that this plant may not be labeled with its scientific name or otherwise may be misidentified, as in a case where a vendor was selling* Alternanthera sessilis *as* H. polysperma.

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40
No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0 √
Unknown	U

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5

Yes, but this species has neither been observed in ballast/fouling ships entering the Great Lakes nor in ports in direct trade with the Great Lakes.	Score x 0.1
No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0
Unknown	U

Vector Potential Scorecard				
Vector	**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind	**0**	x	**0**	Unlikely
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.	**100**	x 0.1	**10**	Low
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)	**100**	x 0.5	**50**	Moderate
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)	**0**	x	**0**	Unlikely
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)	**0**	x	**0**	Unlikely
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling	**0**	x	**0**	Unlikely
Total Unknowns (U)	**0**	**Confidence Level**	High	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

ESTABLISHMENT POTENTIAL RESULTS

Status: **Established in North America, but not including the Great Lakes.**

Hygrophila polysperma **has a moderate probability of establishment if introduced to the Great Lakes (Confidence level: High).**

This perennial aquatic plant inhabits freshwater lakes and streams. The literature predicts that *H. polysperma* has the potential to overwinter in the Great Lakes (Rixon et al. 2005). This species can tolerate temperatures of 4°C (Kasselmann 1995) to 30°C (GISD 2005b). It inhabits waters at depths of 1.5-2.0 m and can photosynthesize in lower light levels than most native aquatic plant species (Spencer and Bowes 1984). *Hygrophila polysperma* is able to draw carbon dioxide from both water and atmosphere (Doyle et al. 2003). This species grows best at pH 5-7 (Spencer and Bowes 1985). Its nonindigenous occurrences in the United States have somewhat similar climates and abiotic conditions as the Great Lakes. Suitable habitats for *H. polysperma* are likely somewhat available in the Great Lakes. The effects of climate change on the Great Lakes, such as warmer water temperatures and shorter duration of ice cover, may improve habitat suitability for this species.

Although it can produce seeds, *Hygrophila polysperma* primarily propagates vegetatively, and forms many adventitious roots at nodes along the stems, which aids the rooting of dispersed fragments (Spencer and Bowes 1985). *Hygrophila polysperma* has a high regrowth potential from stem fragments (Spencer and Bowes 1985). Growth rate of *H. polysperma* is enhanced by higher flow rates (Van Dijk et al. 1986). It can spread rapidly to form dense monoculture stands; it expanded from 0.04 ha to over 0.41 ha in one year (Vandiver 1980). *Hygrophila polysperma* has spread extensively in the southeastern United States and parts of Mexico.

Hygrophila polysperma may have compete with native species. When *H. polysperma* was experimentally grown with *Ludwigia repens*, *L. repens* experienced slower growth rate, produced fewer and shorter stems, and produced fewer branches per stem than when grown without the presence of *H. polysperma* (Doyle et al. 2003). In addition, *H. polysperma* exhibits competitive ability when grown with *L. repens*; *H. polysperma* produces fewer but longer highly branched stems. This species forms dense monocultures that exclude native plants and is a superior competitor because of its low requirements for light and rapid growth (GISD 2005b, Nault and Mikulyuk 2009, Spencer and Bowes 1985, Robinson 2003).

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3

Unknown	U
	6

- *It favors warm climates, although it can tolerate cooler temperatures down to 4˚C (Rixon et al. 2005, USEPA 2008).*
- *It is also a perennial plant with low seasonality, which can maintain shoot biomass year round (Spencer and Bowes 1985, in Doyle et al. 2003).*
- *It can exist in a pH range of 6.5-7.8, a temperature range of 18-30°C (optimum 22-28˚C), and a water hardness level of 30-140 ppm (FNZAS 1988).*
- *Bowes (1987) sets the pH from 5-7, and states its leaves can draw CO_2 from the water and from the atmosphere (Les 2005).*

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9
Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
	8

- *Rixon et al. 2005 predicted* H. polysperma *could overwinter in the Great Lakes.*
- *It favors warm climates, although it can tolerate cooler temperatures down to 4˚C (Rixon et al. 2005, USEPA 2008).*
- *Due to low light saturation and compensation points,* H. polysperma *can photosynthesize at low light levels.*
- *Bowes (1987) states its leaves can draw CO_2 from the water and from the atmosphere (Les 2005).*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
	0

- *This species is an autotroph*

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete	9

native species in the Great Lakes)	
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	0
Unknown	U
	8

- *In general*, H. polysperma *grows and spreads fast, can shade out other submersed plants, and is capable of occupying the whole water column.*
- *According to Doyle et al. (2003),* H. polysperma *has spread rapidly where it exists in Texas, historically occupying up to 20% of the Comal River's area, where it is thought to out-compete native macrophytes.* Hygrophila polysperma *was found to be a superior competitor to* Ludwigia repens*, a morphologically-similar macrophyte which coexists at with* H. polysperma *at a lower abundance in this area (Doyle et al. 2003).*
- *It has outcompeted* Hydrilla verticillata, *another nonindigenous nuisance macrophyte, in the flowing waters of Florida canals; however, it appears to be a poorer competitor in static waters (Van Dijk et al. 1986, Ramey 2001).*
- *In contrast to the competitive ability of* H. polysperma *observed in the southeastern United States., scientists in New Zealand found* H. polysperma *to be a poor competitor when grown with New Zealand native macrophytes,* Egeria densa*, or* Lagarosiphon major *(the latter two macrophytes are native to South America and southern Africa, respectively) (Champion et al. 2007).*
- *During sampling on the San Marcos River, TX, Owens et al. (2001) found that* H. polysperma *was one of the most-abundant species in terms of biomass, accounting for up to a quarter of total plant biomass sampled (second only to the nonindigenous macrophyte* H. verticillata*). The authors observed the formation of large floating mats of* H. polysperma*, which are considered to be detrimental to native vegetation, decreasing sunlight availability, and creating anoxic conditions once decomposition occurs (Owens et al. 2001, Robinson 2003).*
- *"*H. polysperma *may form dense single species stands that often do not provide ideal habitat or food for native wildlife. These native wildlife populations may be forced to relocate or perish, ultimately resulting in a loss of biodiversity and a disruption in the balance of the ecosystem." (Robinson 2003)*

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
	6

- H. polysperma *stems are brittle, and easily fragment. These fragments easily develop new stands from rooted nodes of even small fragments (GISD 2005b).*

- Hygrophila polysperma *reproduces asexually by fragmentation—adventitious roots grow at stem nodes—and sexually, though it is unknown how much of a role seeds play in its spread (Sutton 1996).*

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
	8

- Hygrophila polysperma *reproduces asexually by fragmentation—adventitious roots grow at stem nodes—and sexually, though it is unknown how much of a role seeds play in its spread (Sutton 1996).*

<u>ENVIRONMENTAL COMPATIBILITY</u>

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	6

- *Native to temperate Asia (China - Guangdong, Guangxi, Yunnan) and tropical Asia (Bangladesh, Bhutan, India, Nepal, Pakistan, Cambodia, Laos, Myanmar, Thailand, Vietnam) (Hawaii Pacific Weed Risk Assessment 2012)*
- *North American nonindigenous occurrences are limited to Texas, Florida, South Carolina, and Virginia (USGS NAS 2015, EDDmapS 2015, USEPA 2008).*
- *It favors warm climates, although it can tolerate cooler temperatures down to 4˚C (Rixon et al. 2005, USEPA 2008).*
- *It is also a perennial plant with low seasonality, which can maintain shoot biomass year round (Spencer and Bowes 1985).*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	4

- *It can exist in a pH range of 6.5-7.8, a temperature range of 18-30°C (optimum 22-28˚C), and a water hardness level of 30-140 ppm (FNZAS 1988).*
- *It favors warm climates, although it can tolerate cooler temperatures down to 4˚C (Rixon et al. 2005, USEPA 2008).*
- *Bowes (1987) sets the pH from 5-7, and states its leaves can draw CO_2 from the water and from the atmosphere (Les 2005).*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0
Unknown	U
	3

- *This species occurs in lakes, streams and rivers, still and moving water, up to 3 m (10 ft) in depth. Grows from bottom to water surface (MI DEQ 2012).*
- *It grows from substrate to surface in water up to 10 feet deep, and also around edges, and forms dense stands which can later break off into floating mats—it prefers rivers and streams, but it may be found in slow streams and lakes (Ramey 2001).*
- *There is also a rare terrestrial form that grows in moist soil (McCann et al. 1996).*
- *Due to low light saturation and compensation points,* H. polysperma *can photosynthesize at low light levels.*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6

Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0
Unknown	U
	8

- *Warmer temperatures are likely to improve habitat suitability*

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
	9

- *Due to low light saturation and compensation points,* H. polysperma *can photosynthesize at low light levels.*

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Great Lakes and is not likely to be introduced	-80% total points (at end)

Unknown	U
	9

- *No other species are critical.*

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes)	6
Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0
Unknown	U
	0

- *No facilitating species have been identified.*

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0
Unknown	U
	-5%

- *Grass Carp have low preference for it due to low palatability (Cuda and Sutton 2000) (although according to Ferriter et al. 1997, triploid Grass Carp have been successful at controlling it in canals).*

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9
Frequent, moderate inocula	6
Frequent, small inocula OR infrequent, large inocula	3
Infrequent, small or moderate inocula	0
Unknown	U
	2

- *This species is not commonly sold, there are no known nearby populations*

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
	6

- *This species has been spread to Florida and Texas from southeast Asia.*

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
	6

- *It can spread rapidly to form dense monoculture stands; it expanded from 0.04 ha to over 0.41 ha in one year (Vandiver 1980).*

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing the establishment and spread of this species)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent the establishment and/or spread of this species	0
Unknown	U
	0

Establishment Potential Scorecard				
Points	**Probability for Establishment**	A. Total Points (pre-adjustment)		89
>100	High	**Adjustments**		
		B. Critical species	A*(1- 0%)	89
51-99	Moderate	C. Natural enemy	B*(1- 5%)	84.55
		Control measures	C*(1- 0%)	84.55
0-50	Low	**Potential for Establishment**		Moderate
# of questions answered as "unable to determine"	**Confidence Level**			
0-1	High	Total # of questions unknown		0
2-5	Moderate			
6-9	Low	Confidence Level		High
>9	Very low			

Section C: Potential for Impact

IMPACT RESULTS

Environmental: Moderate

Socio-Economic: High

Beneficial: Moderate

***Hygrophila polysperma* has the potential for moderate environmental impact if introduced to the Great Lakes.**

Hygrophila polysperma can have negative impacts on native species and the ecosystem. This species grows quickly into dense mats that can reduce light availability and dissolved oxygen levels. It shades out native submerged plants (Ramey 2001) and can displace native plants when it occupies the entire water column. Surveys conducted shown that *H. polysperma* can spread rapidly to become one of the most abundant species where it has been introduced, displacing native species (Owens et al. 2001, Vandiver 1980). In Texas, it rapidly spread to occupy 20% of the Comal River's area, where it is thought to displace native macrophytes (Doyle et al. 2003). When *H. polysperma* was grown with *Ludwigia repens*, *L. repens* exhibited slower growth rates compared to when grown alone, suggesting that *H. polysperma* has superior competitive abilities (Doyle et al. 2003). *Hygrophila polysperma* can create anoxic conditions once decomposition occurs (Owens et al. 2001, Robinson 2003). The dense mats of *H. polysperma* can trap sediments and reduce water flows (Robinson 2003).

***Hygrophila polysperma* has the potential for high socio-economic impact if introduced to the Great Lakes.**

Dense mats of *Hygrophila polysperma* can provide breeding grounds for mosquito populations. The mosquito, *Coquillettidia perturbans*, reportedly attaches to submerged roots of *H. polysperma* to complete development and is a vector of eastern and western equine encephalomyelitis (Cuda and Sutton 2000). This species is problematic, as it clogs irrigation and flood control canals and interferes with water control pumping stations (Cuda and Sutton 2000). It is costly to control *H. polysperma* infestations; in 2006, Florida spent $14,000 to control *H. polysperma* covering 206 acres (FDEP 2007). Infestations of *H. polysperma* make navigation difficult and inhibit recreational use (Cuda and Sutton 2000, Robinson 2003). The present of widespread, dense mats of *H. polysperma* can hinder fishing, boating, and swimming activities, causing a reduction lake property value (Robinson 2003).

***Hygrophila polysperma* has the potential for moderate beneficial impact if introduced to the Great Lakes.**

In India, *H. polysperma* seeds are used as a medicine (Spencer and Bowes 1985). *Hygrophila polysperma* is commercially valuable as an ornamental plant and aquarium species (Cuda and Sutton 2000). *Hygrophila polysperma* is advertised for beginner aquarists because it is hardy and easy to grow. This species may increase water clarity when abundant (Osceola County 2012).

POTENTIAL ENVIRONMENTAL IMPACT

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, and it has resulted in the reduction or extinction of one or more native species populations, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems, etc.)	1
Not significantly	0 √
Unknown	U

- *No evidence of allelopathy or parasitism of this species (Hawaii Pacific Weed Assessment 2012)*

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light, etc.)?

Yes, and it has resulted in significant adverse effects (e.g., critical reduction, extinction, behavioral changes, etc.) on one or more native species populations	6
Yes, and it has caused some noticeable stress to or decline of at least one native species population	1 √
Not significantly	0
Unknown	U

- *In general*, H. polysperma *grows and spreads fast, can shade out other submersed plants, and is capable of occupying the whole water column.*
- *According to Doyle et al. (2003),* H. polysperma *has spread rapidly where it exists in Texas, historically occupying up to 20% of the Comal River's area, where it is thought to out-compete native macrophytes.* H. polysperma *was found to be a superior competitor to* Ludwigia repens*, a morphologically-similar macrophyte which coexists at with* H. polysperma *at a lower abundance in this area (Doyle et al. 2003).*
- *It has outcompeted* Hydrilla verticillataI, *another nonindigenous nuisance macrophyte, in the flowing waters of Florida canals; however, it appears to be a poorer competitor in static waters (Van Dijk et al. 1986, Ramey 2001).*
- *In contrast to the competitive ability of* H. polypsperma *observed in the southeastern United States, scientists in New Zealand found* H. polysperma *to be a poor competitor when grown with New Zealand native macrophytes,* Egeria densa*, or* Lagarosiphon major *(the latter two macrophytes are native to South America and southern Africa, respectively) (Champion et al. 2007).*
- *During sampling on the San Marcos River, TX, Owens et al. (2001) found that* H. polysperma *was one of the most-abundant species in terms of biomass, accounting for up to a quarter of total plant biomass sampled (second only to the nonindigenous macrophyte* H. verticillata*). The authors observed the formation of large floating mats of* H. polysperma*, which are considered to be detrimental to native vegetation, decreasing sunlight availability, and creating anoxic conditions once decomposition occurs (Owens et al. 2001, Robinson 2003).*
- H. polysperma *may form dense single species stands that often do not provide ideal habitat or food for native wildlife. These native wildlife populations may be forced to relocate or perish, ultimately resulting in a loss of biodiversity and a disruption in the balance of the ecosystem (Robinson 2003).*

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., added pressure to threatened/endangered species, significant reduction or extinction of any native species populations, creation of a dead end or any other significant alteration in the food web, etc.)	6
Yes, and it has resulted in some noticeable stress to or decline of at least one native species	1

population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	
Not significantly	0
Unknown	U √

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression, etc.)?

Yes, and it has caused a loss or alteration of genes which may be irreversible or has led to the decline or extinction of one or more native species	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0 √
Unknown	U

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles, etc.)?

Yes, and it has had a widespread, long term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been mild	1 √
Not significantly	0
Unknown	U

- *In general,* H. polysperma *grows and spreads fast, can shade out other submersed plants, and is capable of occupying the whole water column.*
- *During sampling on the San Marcos River, TX, Owens et al. (2001) found that* H. polysperma *was one of the most-abundant species in terms of biomass, accounting for up to a quarter of total plant biomass sampled (second only to the nonindigenous macrophyte* H. verticillata*). The authors observed the formation of large floating mats of* H. polysperma*, which are considered to be detrimental to native vegetation, decreasing sunlight availability, and creating anoxic conditions once decomposition occurs (Owens et al. 2001, Robinson 2003).*

E6) Does it alter the physical ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, changes to substrate (physical or chemical), etc.)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1 √
Not significantly	0

Unknown	U

- *In general,* H. polysperma *grows and spreads fast, can shade out other submersed plants, and is capable of occupying the whole water column.*
- *According to Doyle et al. (2003),* H. polysperma *has spread rapidly where it exists in Texas, historically occupying up to 20% of the Comal River's area, where it is thought to replace native macrophytes.*
- *Dense stands of* H. polysperma *trap sediments, slow water flow in irrigation channels and waterways." "Sediment levels increase with increasing* H. polysperma *abundance (Robinson 2003).*

Environmental Impact Total	**3**
Total Unknowns (U)	**1**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	**<u>Moderate</u>**
0	0-1	Low
1	0	
0	≥2	Unknown
1	≥1	

<u>POTENTIAL SOCIO-ECONOMIC IMPACT</u>

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1
Not significantly	0
Unknown	U √

- *Establishment of* H. polysperma *could facilitate growth in pest mosquito (*Coquillettidia perturbans*) populations;* C. perturbans *reportedly attaches to submerged roots of* H. polysperma *to complete development and is a vector of eastern and western equine encephalomyelitis (Cuda and Sutton 2000).*

S2) Does it cause damage to infrastructure (such as water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6 √
Yes, but the costs have been small and are largely reparable or preventable	1
Not significantly	0
Unknown	U

- Hygrophila polysperma *can clog irrigation and flood control canals, and mats of it can block culverts and interfere with water control pumping stations (Cuda and Sutton 2000).*

- *In 2006, there was an estimated 206 acres of* H. polysperma *establishment in Florida, although just $14,000 was allocated by the state for control costs (compared to nearly $12 million spent on another indigenous macrophyte,* Hydrilla verticillata*) (FDEP 2007). When nuisance-levels of establishment do occur,* H. polysperma *is difficult and expensive to control (FDEP 2007).*

S3) Does it negatively affect water quality?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0 √
Unknown	U

S4) Does it harm any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture, etc.)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0 √
Unknown	U

S5) Does it inhibit recreational activities and/or associated tourism (e.g. through frequent water closures, equipment damage, decline of recreational species, etc.)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6
Yes, but negative consequences have been small	1 √
Not significantly	0
Unknown	U

- Hygrophila polysperma *is capable of occupying the whole water column; this reportedly interferes with navigation and can inhibit recreational use for swimming and boating (Cuda and Sutton 2000, Robinson 2003).*

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6
Yes, but negative consequences have been small	1 √
Not significantly	0
Unknown	U

- *The loss of recreational and aesthetic value can cause a decline in surrounding lake property value (Robinson 2003).*

Socio-Economic Impact Total	**8**
Total Unknowns (U)	**1**

Scoring		
Score	# U	**Impact**
>5	Any	**<u>High</u>**
2-5	Any	Moderate
0	0-1	Low
1	0	Low
0	≥2	Unknown
1	≥1	Unknown

<u>POTENTIAL BENEFICIAL EFFECT</u>

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1
Not significantly	0 √
Unknown	U

B2) Is it commercially valuable (e.g. for fisheries, aquaculture, agriculture, bait, ornamental trade, etc.)?

Yes, it is economically important to at least one of these industries	6
Yes, but its economic contribution is small	1 √
Not significantly	0
Unknown	U

- Hygrophila polysperma *is a popular aquarium species and was an important plant grown in the Florida aquarium crop before its prohibition (Cuda and Sutton 2000). It is reportedly sold as an aquarium plant in the Great Lakes region, although the magnitude of its economic importance to this industry is not known (Rixon et al. 2005).*

B3) Is it recreationally valuable (e.g. for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local communities and/or tourism	6
It is sometimes employed recreationally, but adds little value to local communities or	1 √

tourism	
Not significantly	0
Unknown	U

- Hygrophila polysperma *is a popular aquarium species and was an important plant grown in the Florida aquarium crop before its prohibition (Cuda and Sutton 2000).*
- *This species is recommended as hardy for beginners and easy to grow.*

B4) Does the species have some medicinal or research value (outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR It is potentially important to medicine or research and is currently being or scheduled to be studied	1
Not significantly	0 √
Unknown	U

- *In India, the seeds if this species are used medicinally.*

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1 √
Not significantly	0
Unknown	U

- *Large amounts hydrilla, hygrophila or other aquatic plants (excluding algae) can result in increased water clarity, which is often considered desirable.*

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species which is threatened, endangered species, or commercially valuable, etc.)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1
Not significantly	0 √
Unknown	U

Beneficial Effect Total	**3**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	**Moderate**
0	0-1	Low
1	0	
0	≥2	Unknown
1	≥1	

Scientific Name: *Myriophyllum aquaticum*
(Vell.) Verdc.

Common Name: Parrot Feather

Synonyms:

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: High

Hitchhiking/fouling: High

Unauthorized intentional release: High

Stocking/planting/escape from recreational culture: Moderate

Escape from commercial culture: Unknown

Transoceanic shipping: Unlikely

***Myriophyllum aquaticum* has a high probability of introduction to the Great Lakes (Confidence level: Moderate).**

Potential pathway(s) of introduction: Dispersal, Hitchhiking/Fouling, Unauthorized Intentinal Release, Escape from Recreational and Commercial Culture

With established nonindigenous populations in states adjacent to the Great Lakes, parrot feather has potential to be introduced to the Great Lakes from nearby water bodies. The closest parrot feather population to the Great Lakes has been recorded from Meserve Lake, Indiana, which drains though the Pigeon River into the St. Joseph River, a tributary of Lake Michigan (Wersal and Madsen 2011). Fragments of this plant are capable of transport by river currents and could also become attached to or entangled with recreational boats (e.g., propellers, trailer tires) or fishing gear. Its rhizomes are very tough and can be transported long distances on boat trailers, surviving for up to a year when kept moist and cool (Washington State Department of Ecology 2011).

Parrot feather has been an ornamental favorite in hanging baskets, fountains, and aquaria for more than a century due to its blue-green color, feather-like leaves, oxygenating properties, and cascading pattern of growth (Les and Mehrhoff 1999). Often sold under incorrect names, introductions of this species are usually attributed to the water garden and aquarium trades (Davis 1996, UF IFAS 2010, Les and Mehroff 1999). It has escaped cultivation through mechanical fragmentation and unintentional plantings, readily taking root. In a Great Lakes regional study, this aquatic plant was found in 25% of the stores surveyed in Michigan and Ontario, near Lake Erie, between 2002 and 2003 (Rixon et al. 2005). Moreover, water garden plants are often left outside to overwinter, which can lead to unintentional escape during spring flooding. The locations of Ontario water gardens indentified by 2006 survey respondents suggests that many of these gardens are within the coastal regions of four of the five Great Lakes, though if these were also flood-prone areas was not determined (Marson et al. 2009).

Parrot feather is of growing interest for environmental remediation of soil and water contaminated with chlorinated solvents, trinitrotoluene (TNT), and other nitrogenated explosive/aromatic compounds, but this is currently a technology in limited, experimental use (Medina et al. 2000, Nwoko 2010).

Among the Great Lakes states and provinces, *M. aquaticum* is prohibited in Illinois, Michigan, and Wisconsin and regulated in Minnesota. Furthermore, it is listed as a noxious weed by nine non-Great Lakes states (Alabama, Connecticut, Idaho, Maine, Massachusetts, Maryland, New Hampshire, Vermont, and Washington) (IISG 2011, GLPANS 2008, WIDNR 2011). Without more stringent laws regulating sale and disposal throughout the entire region, introduction could occur through disposal of aquarium fragments, unintentional escape from culture, or intentional unauthorized planting to support live trade.

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100 √
No, this species does not occur near waters connected to the Great Lakes basin and/or is not mobile or able to be transported by wind or water.	0
Unknown	U

- Myriophyllum aquaticum *has been recorded in Meserve Lake, Indiana (Wersal and Madsen 2011).*
- *Reproduction occurs by fragmentation of emergent and/or submersed shoots, roots, rhizomes, or attached plant fragments (UF IFAS 2010, Mabulu 2005). Fragments are capable of transport along river currents.*

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1 √
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25
Unknown	U

- *The closest* M. aquaticum *population to the Great Lakes has been recorded from Meserve Lake, Indiana, which drains though the Pigeon River into the St. Joseph River, a tributary of Lake Michigan (Wersal and Madsen 2011).*

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100 √
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0
Unknown	U

- *Fragments of parrot feather could become attached to or entangled with recreational boats (e.g., propellers, trailer tires) or fishing gear.*
- *Its rhizomes are very tough and can be transported long distances on boat trailers, surviving for up to a year when kept moist and cool (Washington State Department of Ecology 2011).*

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1 √
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1
Unknown	U

- *The closest* M. aquaticum *population to the Great Lakes has been recorded from Meserve Lake, Indiana, which drains though the Pigeon River into the St. Joseph River, a tributary of Lake Michigan (Wersal and Madsen 2011).*

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a) Is this species sold at aquarium/pet/garden stores ("brick & mortar" or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100 √
No, this species this species is rarely/never sold.	0
Unknown	U

- *Often sold under incorrect names, introductions of this species are usually attributed to the water garden and aquarium trades (Davis 1996, Les and Mehroff 1999, UF IFAS 2010).*

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1 √
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1
Unknown	U

- *Parrot Feather has been an ornamental favorite in hanging baskets, fountains, and aquaria for more than a century due to its blue-green color, feather-like leaves, oxygenating properties, and cascading pattern of growth (Les and Mehrhoff 1999).*
- *In a Great Lakes regional study, this aquatic plant was found in 25% of the Michigan and Ontario (near Lake Erie) stores surveyed between 2002 and 2003 (Rixon et al. 2005).*

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100 √
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0
Unknown	U

- *Often sold under incorrect names, introductions of this species are usually attributed to the water garden and aquarium trades (Davis 1996, UF IFAS 2010, Les and Mehroff 1999). Parrot feather has escaped cultivation through mechanical fragmentation and unintentional plantings, readily taking root.*
- *Water garden plants are often left outside to overwinter, which can lead to unintentional escape during spring flooding (Marson et al. 2009).*
- *Parrot Feather is of growing interest for environmental remediation of soil and water contaminated with chlorinated solvents, trinitrotoluene (TNT), and other nitrogenated explosive/aromatic compounds (Medina et al. 2000, Nwoko 2010).*

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75 √
This activity is <u>likely</u> to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces), this activity <u>may</u> occur within 20 km of the basin because of the species' popularity/value.	Score x 0.25
Unknown	U

- *Among the Great Lakes states and provinces,* M. aquaticum *is prohibited in Illinois, Michigan, and Wisconsin and regulated in Minnesota. Furthermore, it is listed as a noxious weed by nine non-Great Lakes states (Alabama, Connecticut, Idaho, Maine, Massachusetts, Maryland, New Hampshire, Vermont, and Washington) (IISG 2011, GLPANS 2008, WIDNR 2011).*
- *The locations of Ontario water gardens identified by 2006 survey respondents suggest that many of these gardens are within the coastal regions of four of the five Great Lakes (Marson et al. 2009).*

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100 √
No, this species is not commercially cultured in or transported through the Great Lakes region.	0

Unknown	U

- *Parrot Feather is commercially supplied to aquarium and water garden stores for resale.*

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U √

- *At the time of this assessment, the nature of commercial activity involving parrot feather in the Great Lakes basin was not known.*

<u>POTENTIAL INTRODUCTION VIA SHIPPING</u>

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40
No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0 √
Unknown	U

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5
Yes, but this species has neither been observed in ballast/fouling ships entering the Great Lakes nor in ports in direct trade with the Great Lakes.	Score x 0.1

No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0
Unknown	U

Vector Potential Scorecard				
Vector	**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind	**100**	x 1	**100**	High
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.	**100**	x 1	**100**	High
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)	**100**	x 1	**100**	High
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)	**100**	x 0.75	**75**	Moderate
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)	**100**	x U	**U**	Unknown
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling	**0**	x	**0**	Unlikely
Total Unknowns (U)	**1**	**Confidence Level**	Moderate	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

ESTABLISHMENT POTENTIAL RESULTS

Status: **Established in North America, but not the Great Lakes**

Myriophyllum aquaticum **has a moderate probability of establishment if introduced to the Great Lakes (Confidence level: Moderate).**

Myriophyllum aquaticum is a hardy species with broad environmental tolerances. It occurs as a floating plant in the deep water of nutrient-enriched lakes like the Great Lakes (Washington State Department of Ecology 2011). It is known to tolerate freezing temperatures in California's Bay area winters (Aiken 1981). However, this plant can be killed by extended periods of frost (WIDNR 2011) and so may benefit from warmer winters predicted to result from climate change.

Parrot feather grows vigorously and quickly following invasion in new habitats, forming dense canopies that occupy large amounts of space and block sunlight and oxygen exchange. As a result, this species outcompetes and replaces native flora that might be of more value to fish and wildlife (Stiers et al. 2011, WIDNR 2011).

Reproduction and dispersal of *M. aquaticum* in North America occurs by vegetative fragmentation, which is an effective method for short-range, but not long-range, dispersal (Les and Mehrhoff 1999). Although parrot feather's natural dispersal potential is limited, this species is widespread outside its native range (Moody and Les 2010). *Myriophyllum aquaticum* has expanded its range mainly in the southern United States and may be relatively innocuous in the northeast due to a smaller number of occurrences (Hoyer et al. 1996). Nonetheless, this species has survived in southern New England and caused serious local infestations (WIDNR 2011). The rapid spread of *M. aquaticum* is correlated with its widespread cultivation and the transport of fragments by waterfowl or vehicles. When transport agents are not present, the threat of its escape and establishment depends more on the number of localities where it is grown. Unfortunately, *M. aquaticum* remains widely available from sources of cultivated water plants and dealers occasionally plant it intentionally to propagate a local supply (Aiken 1981, Les and Mehrhoff 1999).

Nonindigenous *M. aquaticum* specimens collected from geographically diverse locations in North America have been found to have identical ITS genotypes and are all female. Seed production has not been recorded (Moody and Les 2010).

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
	8

- Myriophyllum aquaticum *is a hardy species with broad environmental tolerances. This species displays photosynthetic activity at pH levels of 6 to 8.5, depths of 0 to 10 meters, and temperatures from 10°C to 30°C, though it can survive even broader ranges (Robinson 2003, WIDNR 2011).*

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9
Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
	4

- Myriophyllum aquaticum *is known to tolerate freezing temperatures in California's Bay area winters (Aiken 1981). However, this plant can be killed by extended periods of frost (WIDNR 2011).*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
	0

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	0

Unknown	U
	7

- Myriophyllum aquaticum *grows vigorously and quickly following invasion in new habitats, forming dense canopies that occupy large amounts of space and block sunlight and oxygen exchange. As a result, this species outcompetes and replaces native flora that might be of more value to fish and wildlife (Stiers et al. 2011, WIDNR 2011).*

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
	U

- *Parrot feather is a dioecious species, however only pistillate (female) plants are found outside of South America. Staminate (male) plants are rare even in native populations of South America (Orchard 1981). For this reason, seed production is not known to occur (Aiken 1981) and reproduction is exclusively vegetative in North America (Orchard 1981).*

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
	6

- *Reproduction and dispersal of* M. aquaticum *in North America occurs by vegetative fragmentation, which is an effective method for short-range but not long-range dispersal (Les and Mehrhoff 1999).*

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	6

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	9

- Myriophyllum aquaticum *occurs as a floating plant in the deep water of nutrient-enriched lakes like the Great Lakes (Washington State Department of Ecology 2011).*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0
Unknown	U
	9

- Myriophyllum aquaticum *is a hardy species that can be established in a wide range of aquatic habitats. The species prefers nutrient rich and quiet or slow moving shallow waters but it has also been known to occur as a floating plant in the deep water of nutrient-enriched lakes. The species can also tolerate the salinity of coastal or brackish waters and is able to withstand routine water level fluctuations (Aiken 1981, Robinson 2003).*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0
Unknown	U
	6

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
	9

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for	3

the species being assessed	
Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Great Lakes and is not likely to be introduced	-80% total points (at end)
Unknown	U
	0

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes)	6
Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0
Unknown	U
	0

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0

Unknown	U
	0

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9
Frequent, moderate inocula	6
Frequent, small inocula OR infrequent, large inocula	3
Infrequent, small or moderate inocula	0
Unknown	U
	U

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
	9

- *Although parrot's feather's natural distribution is limited, it is widespread outside its native range. (Moody and Les 2010).* Myriophyllum aquaticum *has expanded its range mainly in the southern United States and may be relatively innocuous in the northeast due to a smaller number of occurrences (Hoyer et al. 1996). Nonetheless, this species has survived in southern New England and caused serious local infestations (WIDNR 2011).*

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6

Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
	5

- *The rapid spread of* M. aquaticum *is correlated with its widespread cultivation and the transport of fragments by waterfowl or vehicles. When transport agents are not present, the threat of its escape and establishment depends more on the number of localities where it is grown. Unfortunately,* M. aquaticum *remains widely available from sources of cultivated water plants and dealers occasionally plant it intentionally to propagate a local supply (Aiken 1981, Les and Mehrhoff 1999).*

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing the establishment and spread of this species)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent the establishment and/or spread of this species	0
Unknown	U
	0

Establishment Potential Scorecard				
Points	**Probability for Establishment**	A. Total Points (pre-adjustment)		78
>100	High	**Adjustments**		
		B. Critical species	A*(1- 0%)	78
51-99	Moderate	C. Natural enemy	B*(1- 0%)	78
		Control measures	C*(1- 0%)	78
0-50	Low	**Potential for Establishment**		Moderate
# of questions answered as “unable to determine”	**Confidence Level**			
0-1	High			2

2-5	Moderate	Total # of questions unknown	
6-9	Low	Confidence Level	Moderate
>9	Very low		

Section C: Potential for Impact

IMPACT POTENTIAL RESULTS

Environmental: High

Socio-Economic: Moderate

Beneficial: Moderate

***Myriophyllum aquaticum* has the potential for high environmental impact if introduced to the Great Lakes.**

The United States Environmental Protection Agency (USEPA) (2008) predicted that *M. aquaticum* could have a high impact and spread rate in the Great Lakes, as it is adaptive to a variety of environments. According to Les and Mehrhoff (1999), rapid spread has been relatively common in this macrophyte's North American invasion history (Les and Mehrhoff 1999). Outside the United States, a risk assessment prepared for Australia in 1995 by Pacific Island Ecosystems at Risk recommended rejection of the plant for import on mainland due to its likelihood of becoming a pest (Mabulu 2005). By 2002, parrot feather was assessed as one of the top 200 invasive naturalized plants in Southeast Queensland, Australia (ranked #69 of 200) (Queensland Herbarium 2002).

Dense infestations of parrot feather can rapidly overtake small ponds and sloughs, changing their physical and chemical properties, including impeding water flow, which can result in increased flood duration and intensity. The spread of aquatic nonindigenous plants into a waterbody can also lead to increased rates of evapotranspiration and water loss. One mesocosm experiment found that colonization by *M. aquaticum* was correlated to an increase in water loss of about 1.5 to 2 times that experienced by an open water surface (Rosa et al. 2009).

Myriophyllum aquaticum can dramatically alter ecosystems by shading out algae, pondweeds, and coontail on which waterfowl feed (Ferreira and Moreira 1994, Washington State Department of Ecology 2011). Floating mats of *M. aquaticum* have been measured at up to 26 kg of fresh weight in Europe and are capable of reducing the oxygen content of the water below to <1 mg O_2L^{-1}, which can be detrimental to fish (Hussner and Meyer 2009). In Germany, the infestation of these mats created anoxic, shaded conditions in shallow waters, and appeared to be correlated with a decline in native macrophyte diversity (Hussner et al. 2010).

In Chinese laboratory experiments, parrot feather outcompeted native species with respect to relative growth rate, with the most significant results on high-nutrient sediment (Xie et al. 2010). A separate mesocosm study by Wersal and Madsen (2011) found that the yield (biomass) of *M. aquaticum* was positively related to tissue nitrogen content, suggesting that high levels of nitrogen contribute to nuisance levels of growth. However, an inverse relationship existed between *M. aquaticum* yield and tissue phosphorus content. Wersal and Madsen (2011) proposed that high levels of phosphorus favored the growth of algae (superior competitors in phosphorus uptake) causing shading in the water column and suppressing the growth of *M. aquaticum* (Wersal and Madsen 2011).

Stiers et al. (2011) compared Belgian lake sites that were heavily invaded (90-100% cover), semi-invaded (~25% cover), and uninvaded by *M. aquaticum* and found that native species richness was 57% lower in heavily invaded sites relative to uninvaded sites. Parrot feather cover was also negatively correlated with invertebrate species richness and abundance. The authors observed lowered levels of dissolved oxygen at some sites, as well as a dense mat of decomposed plant litter and sediments at the bottom of heavily-invaded sites; they hypothesized that this condition created unsuitable habitat for invertebrate colonization (Stiers et al. 2011). Plant species that are rare (*Utricularia vulgaris*) and vulnerable (*Hydrocharis morsus-ranae*) IUCN Red List species in Belgium were absent in heavily invaded sites but present in semi-invaded sites (Steirs et al. 2011, Lansdown 2014). Furthermore, mayflies (*Caenis* spp.) were present in uninvaded sites, but were not reported in invaded sites (Steirs et al. 2011).

Myriophyllum aquaticum can also alter the cycling of heavy metals in aquatic systems. Cardwell et al. (2002) found that *M. aquaticum* accumulated the highest overall levels of metals (zinc, cadmium, copper, and lead) in its tissues of all 15 aquatic plants that underwent testing. While this suggests that *M. aquaticum* could be used as an important indicator species (see below), the consumption of *M. aquaticum* by grazers could increase the bioaccumulation of heavy metals in the food web.

***Myriophyllum aquaticum* has the potential for moderate socio-economic impact if introduced to the Great Lakes.**

Parrot feather infestations have been reported in both natural and man-made water bodies, including lakes, ponds, canals, drainage and irrigation ditches, and lagoons. Plants and floating mats of vegetation are sometimes uprooted, choking waterways, inhibiting navigation, and potentially blocking pumps or drainage (Engineer Research and Development Center 2007, Sheppard et al. 2006). Dense growth can also diminish the recreational value and seriously affect the perceived aesthetic qualities of infested waterways (Banfield 2008, Washington State Department of Ecology 2011).

Myriophylum aquaticum monocultures provide prime mosquito habitat; higher parrot feather density has been correlated with higher mosquito egg and larval abundance (Orr and Resh 1992), which may lead to increased prevalence of mosquito-born diseases.

Myriophyllum spp. have invaded rice paddies could adversely affect wild rice (*Zizania palustris*) found in the upper Great Lakes (Quayyum et al. 1999). One account by South African farmers also reported that tobacco crops gained a red tint (reducing the sale value of the crop) when irrigated with water from an area colonized by *M. aquaticum* roots (Cilliers 1999).

***Myriophyllum aquaticum* has the potential for moderate potential benefits if introduced to the Great Lakes.**

Assessment protocols have been developed using *M. aquaticum* as a primary indicator species of sediment toxicity in potentially polluted areas (Feiler et al. 2004, Knauer et al. 2008). It is an important species in the aquarium trade and can be found in shops in both the American and Canadian Great Lakes regions (Marson et al. 2009, Rixon et al. 2005). It is reportedly sold as an "oxygenating plant" in Europe (Sheppard et al. 2006).

Parrot feather may provide cover for some aquatic organisms (Washington State Department of Ecology 2011). Parker et al. (2007) found that beavers (*Castor canadensis*) in Georgia fed on *M. aquaticum* to the extent that invasive populations were reduced, although no strong preference for this plant species over others was documented. *Myriophyllum aquaticum* could be used for nitrogen and phosphorus remediation (e.g., in a constructed wetland remediating nutrient runoff), but Polomski et al. (2009) found that other invasive macrophytes (*Eichhornia crassipes* and *Pistia stratiotes*) had equal or greater uptake efficiency levels relative to *M. aquaticum*. Parrot feather can also aid in environmental remediation of soil and water contaminated with chlorinated solvents, trinitrotoluene (TNT), and other nitrogenated explosive/aromatic compounds (Medina et al. 2000, Nwoko 2010).

POTENTIAL ENVIRONMENTAL IMPACT

NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1
Not significantly	0
Unknown	U √

- *Cardwell et al. (2002) found that* M. aquaticum *accumulated the highest overall levels of metals (zinc, cadmium, copper, and lead) in its tissues of all 15 aquatic plants that underwent testing. The consumption of* M. aquaticum *by grazers could increase the bioaccumulation of heavy metals in the food web.*

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6 √
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1
Not significantly	0
Unknown	U

- *Stiers et al. (2011) compared Belgian lake sites that were heavily invaded (90-100% cover), semi-invaded (~25% cover) and uninvaded by* M. aquaticum*, and found that native species richness was 57% lower in heavily invaded sites relative to uninvaded sites.* Myriophyllum aquaticum *cover was also negatively correlated with invertebrate species richness and abundance.*
- *Plant species that are rare (*Utricularia vulgaris*) and vulnerable (*Hydrocharis morsus-ranae*) IUCN Red List species in Belgium were absent in heavily invaded* M. aquaticum *sites but present in semi-invaded sites (Steirs et al. 2011, Lansdown 2014).*
- *In China,* M. aquaticum *outcompeted native species in the laboratory with respect to relative growth rate, with the most significant results on high-nutrient sediment (Xie et al. 2010).*
- *In a mesocosm study, Wersal and Madsen (2011) found that the yield (biomass) of* M. aquaticum *was positively related to tissue nitrogen content, suggesting that high levels of nitrogen contribute to nuisance levels of*

growth. However, an inverse relationship existed between M. aquaticum *yield and tissue phosphorus content. Wersal and Madsen (2011) proposed that high levels of phosphorus favored the growth of algae (superior competitors in phosphorus uptake) causing shading in the water column and suppressing the growth of* M. aquaticum *(Wersal and Madsen 2011).*

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in the food web)	6
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	1
Not significantly	0
Unknown	U √

- Myriophyllum aquaticum *can dramatically alter ecosystems by shading out algae, pondweeds, and coontail on which waterfowl feed (Ferreira and Moreira 1994, Washington State Department of Ecology 2011).*

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0 √
Unknown	U

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6 √
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1
Not significantly	0
Unknown	U

- *Floating mats of* M. aquaticum *have been measured at up to 26 kg of fresh weight in Europe and are capable of reducing the oxygen content of the water below to <1 mg O_2L^{-1} (Hussner and Meyer 2009).*
- *In Germany, the infestation of* M. aquaticum *mats created anoxic, shaded conditions in shallow waters, and appeared to be correlated with a decline in native macrophyte diversity (Hussner et al. 2010).*

- Myriophyllum aquaticum *can alter the cycling of heavy metals in aquatic systems. Cardwell et al. (2002) found that* M. aquaticum *accumulated the highest overall levels of metals (zinc, cadmium, copper, and lead) in its tissues of all 15 aquatic plants that underwent testing.*

E6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6 √
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1
Not significantly	0
Unknown	U

- Myriophyllum aquaticum *can dramatically alter ecosystems by shading out algae in the water column (Washington State Department of Ecology 2011).*
- *In Germany, the infestation of* M. aquaticum *mats created shaded conditions in shallow waters, and appeared to be correlated with a decline in native macrophyte diversity (Hussner et al. 2010).*
- *Dense infestations can rapidly overtake small ponds and sloughs, changing their physical and chemical properties, including impeding water flow, which can result in increased flood duration and intensity.*
- *The spread of aquatic nonindigenous plants into a waterbody can also lead to increased rates of evapotranspiration and water loss. One mesocosm experiment found that colonization by* M. aquaticum *was correlated to an increase in water loss of about 1.5 to 2 times that experienced by an open water surface (Rosa et al. 2009).*
- *Senescence of parrot feather can leave a dense mat of decomposed plant litter and sediments at the bottom of heavily-invaded sites that may create unsuitable habitat for invertebrate colonization (Stiers et al. 2011).*

Environmental Impact Total	**18**
Total Unknowns (U)	**2**

Scoring		
Score	# U	**Impact**
>5	Any	<u>**High**</u>
2-5	Any	Moderate
0	0-1	Low
1	0	
0	≥2	Unknown
1	≥1	

POTENTIAL SOCIO-ECONOMIC IMPACT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1
Not significantly	0
Unknown	U √

- Myriophyllum aquaticum *monocultures provide prime mosquito habitat; increasing density has been correlated with increasing egg and larval abundance in invaded waterbodies (Orr and Resh 1992), which may lead to increased prevalence of mosquito-borne diseases.*

S2) Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1 √
Not significantly	0
Unknown	U

- *Plants and floating mats of vegetation are sometimes uprooted, choking waterways, inhibiting navigation, and potentially blocking pumps or drainage (Engineer Research and Development Center 2007, Sheppard et al. 2006).*

S3) Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0 √
Unknown	U

S4) Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0
Unknown	U √

- *One account by South African farmers reported that tobacco crops gained a red tint (reducing the sale value of the crop) when irrigated with water from an area colonized by the roots of* M. aquaticum *(Cilliers 1999).*

- Myriophyllum *spp. have invaded rice paddies could adversely affect wild rice* Zizania palustris *found in the upper Great Lakes (Quayyum et al. 1999).*

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6
Yes, but negative consequences have been small	1 √
Not significantly	0
Unknown	U

- *Plants and floating mats of* M. aquaticum *are sometimes uprooted, choking waterways and inhibiting navigation (Engineer Research and Development Center 2007, Sheppard et al. 2006). Dense growth can diminish the recreational value of water bodies (Washington State Department of Ecology 2011).*

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6
Yes, but negative consequences have been small	1 √
Not significantly	0
Unknown	U

- *Like other plants that form dense growths,* M. aquaticum *can seriously affect the perceived aesthetic qualities of infested waterways (Banfield 2008).*

Socio-Economic Impact Total	**3**
Total Unknowns (U)	**2**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	**<u>Moderate</u>**
0	0-1	Low
1	0	Low
0	≥2	Unknown
1	≥1	Unknown

POTENTIAL BENEFICIAL EFFECT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular effect. An "Unknown" response is appropriate if the potential for a particular effect might be inferred but has not been explicitly reported or if there is an unresolved debate about a particular effect.

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1
Not significantly	0 √
Unknown	U

B2) Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?

Yes, it is economically important to at least one of these industries	6
Yes, but its economic contribution is small	1 √
Not significantly	0
Unknown	U

- *Parrot feather is an important species in the aquarium trade, and can be found in shops in both the American and Canadian Great Lakes regions (Marson et al. 2009, Rixon et al. 2005). It is reportedly sold as an "oxygenating plant" in Europe (Sheppard et al. 2006).*

B3) Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local communities and/or tourism	6
It is sometimes employed recreationally, but adds little value to local communities or tourism	1 √
Not significantly	0
Unknown	U

- *Parrot feather is an important species in the aquarium trade, and can be found in shops in both the American and Canadian Great Lakes regions (Marson et al. 2009, Rixon et al. 2005). It is reportedly sold as an "oxygenating plant" in Europe (Sheppard et al. 2006).*

B4) Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR It is potentially important to medicine or research and is currently being or scheduled to be studied	1 √

Not significantly	0
Unknown	U

- *Assessment protocols have been developed using* M. aquaticum *as a primary indicator species of sediment toxicity in potentially polluted areas (Feiler et al. 2004, Knauer et al. 2008).*

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1 √
Not significantly	0
Unknown	U

- Myriophyllum aquaticum *could be used for nitrogen and phosphorus remediation (e.g., in a constructed wetland remediating nutrient runoff), but Polomski et al. (2009) found that other invasive macrophytes (*Eichhornia crassipes *and* Pistia stratiotes*) had equal or greater uptake efficiency levels relative to* M. aquaticum.
- *Parrot feather could also be used for environmental remediation of soil and water contaminated with chlorinated solvents, trinitrotoluene (TNT), and other nitrogenated explosive/aromatic compounds (Medina et al. 2000, Nwoko 2010).*

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1
Not significantly	0
Unknown	U √

- *It may provide cover for some aquatic organisms (Washington State Department of Ecology 2011).*
- *Parker et al. (2007) found that beavers (*Castor canadensis*) in Georgia fed on* M. aquaticum *to the extent that invasive populations were reduced, although no strong preference for this plant species over others was documented.*

Beneficial Effect Total	**4**
Total Unknowns (U)	**1**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	**Moderate**
0	0-1	Low
1	0	Low
0	≥2	Unknown
1	≥1	Unknown

Scientific Name: *Pistia stratiotes* Linnaeus

Common Name: Water Lettuce

Synonyms: laitue d'eau, pistie (French), Lechuguilla de agua, lechuguita de agua, repollo de agua (Spanish)

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: High

Hitchhiking/fouling: High

Unauthorized intentional release: High

Stocking/planting/escape from recreational culture: High

Escape from commercial culture: Unknown

Transoceanic shipping: Unlikely

***Pistia stratiotes* has a high probability of introduction to the Great Lakes (Confidence level: Moderate).**

Potential pathway(s) of introduction: Dispersal, Hitchhiking/Fouling, Unauthorized Intentional Release, Escape from Recreational and Commecial Culture

Pistia stratiotes occurs in close proximity to the Great Lakes basin. It is found during spring through the fall in Lake St. Clair (Adebayo et al. 2011), Detroit River, and inland waters in Ontario, Ohio, New York, and Minnesota (Cochran et al. 2006).

Pistia stratiotes spreads via vegetative fragmentation and water dispersal. Fragments or seeds of *P. stratiotes* may potentially be introduced to the Great Lakes by dispersal. *Pistia stratiotes* can be unintentionally transported to the Great Lakes by hitchhiking on boats and recreational equipment.

This species is part of the aquarium trade (Parsons and Cuthbertson 2001). According to a study on aquarium and pet stores near Lakes Erie and Ontario, 20% of stores surveyed carried *Pistia stratiotes* (Rixon et al. 2005). *Pistia stratiotes* may be released into the Great Lakes when aquarists dispose this plant into waterways. This species is planted in water gardens and may be unintentionally introduced to the Great Lakes. It is unknown whether this species is commercially cultured in the Great Lakes region. *Pistia stratiotes* is not known to be taken up or transported by ballast water.

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100 √
No, this species does not occur near waters connected to the Great Lakes basin and/or is not mobile or able to be transported by wind or water.	0
Unknown	U

- *Water lettuce can spread between water bodies via plant material, such as rosettes or seeds (OMNR 2010).*
- *Water lettuce is found during the spring, summer, and fall seasons at various locations (Lake St. Clair, Detroit River, and inland areas of Ontario, Ohio, New York, Minnesota) in the Great Lakes basin (Cochran et al. 2006, OMNR 2010, Adebayo et al. 2011, MISIN 2013, USDA NRCS 2013).*
- *Water lettuce likely has not yet established reproducing populations within the Great Lakes basin (Eyraud and MacIsaac 2013).*

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1 √
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25
Unknown	U

- *Water lettuce is found during the spring, summer, and fall seasons at various locations (Lake St. Clair, Detroit River, and inland areas of Ontario, Ohio, New York, Minnesota) in the Great Lakes basin (Cochran et al. 2006, OMNR 2010, Adebayo et al. 2011, MISIN 2013, USDA NRCS 2013).*
- *Water lettuce likely has not yet established reproducing populations within the Great Lakes basin (Eyraud and MacIsaac 2013).*

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100 √
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0
Unknown	U

- *This species can be transported with boats, boat trailers, and other equipment (e.g., fishing or scuba gear) (OMNR 2010).*

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1 √
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1
Unknown	U

- *Water lettuce is found during the spring, summer, and fall seasons at various locations (Lake St. Clair, Detroit River, and inland areas of Ontario, Ohio, New York, Minnesota) in the Great Lakes basin (Cochran et al. 2006, OMNR 2010, Adebayo et al. 2011, MISIN 2013, USDA NRCS 2013).*
- *Water lettuce likely has not yet established reproducing populations within the Great Lakes basin (Eyraud and MacIsaac 2013).*

<u>POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE</u>

3a) Is this species sold at aquarium/pet/garden stores ("brick & mortar" or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100 √
No, this species this species is rarely/never sold.	0
Unknown	U

- *Water lettuce is also used as an ornamental plant in aquaria, ponds, and outdoor water gardens; it may be planted near or along shorelines and escape into new areas as plant material is discarded into a waterway or carried off by flooding during rain events (OMNR 2010).*

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1 √
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1
Unknown	U

- *An internet search of "water lettuce for sale" yielded many online stores that would ship this species, as well as availability for direct sale at local garden supply stores.*
- *Sale was also verified in the Great Lakes region by (Adebayo et al. 2011).*
- *According to a survey of aquarium and pet stores near Lakes Erie and Ontario, 20% of stores surveyed carried* Pistia stratiotes *(Rixon et al. 2005).*

<u>POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE</u>

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100 √
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0
Unknown	U

- *Water lettuce is also used as an ornamental plant in aquaria, ponds, and outdoor water gardens; it may be planted near or along shorelines and escape into new areas as plant material is discarded into a waterway or carried off by flooding during rain events (OMNR 2010).*

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1 √
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is likely to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces), this activity may occur within 20 km of the basin because of the species' popularity/value.	Score x 0.25
Unknown	U

- *This species is not on the United States Federal Noxious Weed List, nor on any Great Lakes state noxious weed list (only listed in Alabama, California, Connecticut, Florida, Mississippi, South Carolina, and Texas; import prohibited in Louisiana) (USDA NRCS 2013).*
- *Sale was also verified in the Great Lakes region by (Adebayo et al. 2011).*

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100
No, this species is not commercially cultured in or transported through the Great Lakes region.	0
Unknown	U √

- *It is not known if this species is commercially cultured in the Great Lakes.*

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5

This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U √

- *This species is not on the United States* <u>*Federal Noxious Weed List*</u>*, nor on any Great Lakes state noxious weed list (only listed in Alabama, California, Connecticut, Florida, Mississippi, South Carolina, and Texas; import prohibited in Louisiana) (USDA NRCS 2013).*
- *It is not known if this species is commercially cultured in the Great Lakes.*

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40
No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0 √
Unknown	U

- *This species requires sufficient light, warm temperatures, and fresh water and is thus unlikely to survive ballast water regulations.*

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5
Yes, but this species has neither been observed in ballast/fouling ships entering the Great Lakes nor in ports in direct trade with the Great Lakes.	Score x 0.1
No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0
Unknown	U

Vector Potential Scorecard					
Vector		**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind		**100**	x 1	**100**	High
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.		**100**	x 1	**100**	High
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)		**100**	x 1	**100**	High
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)		**100**	x 1	**100**	High
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)		**U**	x U	**U**	Unknown
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling		**0**	x	**0**	Unlikely
Total Unknowns (U)	**2**	**Confidence Level**		Moderate	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

ESTABLISHMENT POTENTIAL RESULTS

Status: Established in North America, but not including the Great Lakes.
***Pistia stratiotes* has a moderate probability of establishment if introduced to the Great Lakes (Confidence level: High).**

Pistia stratiotes inhabits tropical and subtropical lakes, reservoirs, and slow-flowing streams (Parsons and Cuthbertson 2001). *Pistia stratiotes* does best in warm waters, as it is killed by frost. *Pistia stratiotes* exhibits optimal growth at water temperatures of 22-30°C (Kasselmann 1995). It can tolerate temperatures as low as 15°C and as high as 35°C. This species has been observed to overwinter in the Erft River, Germany; the water temperature in that river is abnormally warm (>11°C) and only leaves that remained submerged survived (Hussner et al. 2010). Its seeds can survive for at least 2 months in water at 4°C and for a few weeks in ice at -5°C (Parsons and Cuthbertson 2001); its seeds have the potential to overwinter in the Great Lakes. *Pistia stratiotes* reproduces rapidly though seed production and vegetative fragmentation. Its short, brittle stolons that are involved in vegetative fragmentation may aid its establishment in the Great Lakes.

Pistia stratiotes has a widespread distribution encompassing 40 countries (Holm 1991), and occurs on every continent except Antarctica. This species is capable of expanding its distribution quickly. After 1 year, this species had rapidly spread and covered an entire lake (Sridhar and Sharma 1980, Venema 2001).

The native and introduced ranges of *P. stratiotes* have somewhat similar climatic and abiotic conditions as the Great Lakes; the Great Lakes may have lower air temperatures and lower water temperatures. The effects of climate change may make the Great Lakes a more suitable environment for the establishment of *P. stratiotes*. Warmer water temperatures and shorter duration of ice cover may aid the establishment of *P. stratiotes*. Freshwater lakes and slow-flowing streams in the Great Lakes may provide suitable habitats for *P. stratiotes*.

Pistia stratiotes has outcompeted other species where it has been introduced. Three years after *P. stratiotes* was first observed in Slovenia, it had covered the whole water surface and populations of native freshwater plants, *Ceratophyllum demersum*, *Myriophyllum spicatum*, *Najas marina*, and *Trapa natans*, had declined (Šajna et al. 2007).

Surveillance and management efforts are currently underway to detect, control, and/or eradicate this plant in Michigan (MI DEQ 2013) and Wisconsin (Falck et al. 2010). However, a basin-wide monitoring program is lacking (Dupre 2011).

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
	4

- *Rivers (2002) noted that for* P. stratiotes *to survive, it requires a wet, temperate habitat. It is usually found in lakes and rivers; however, it can also survive in mud.*
- Pistia stratiotes *can endure temperature extremes of 15°C (59°F) and 35°C (95°F). The optimal growth temperature range for the plant is 22-30°C (72-86°F) (Kasselmann 1995).*

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9
Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0
Unknown	U
	1

- Pistia stratiotes *can endure temperature extremes of 15°C (59°F) and 35°C (95°F). The optimal growth temperature range for the plant is 22-30°C (72-86°F) (Kasselmann 1995).*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
	0

- *This species is an autotroph.*

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a	0

species in the Great Lakes)	
Unknown	U
	9

- *Mats reduce or eliminate light for submerged hydrophytes, epiphytic, and planktonic algae (Attionu 1976).*
- *In Slovenia, as early as three years after the first observation of* P. stratiotes*, native freshwater plants (*Ceratophyllum demersum *L.*, Myriophyllum spicatum *L.*, Najas marina *L. and* Trapa natans L.) *in this species-rich wetland habitat were on decline, because the whole water surface was covered with a dense mat that remained closed even during the winter (Šajna et al. 2007).*
- *Oxygen and light limitations by this species kill native plants, fish, and wildlife (Chokder 1968, FDEP 2007).*

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3
Low	0
Unknown	U
	6

- *This species has prolific seed production (>2000/m^2) (Randall 2003).*
- *Many species in the Araceae Family are rhizomatous.*

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
	7

- *Water lettuce has short, brittle stolons that make it susceptible to vegetative reproduction (Rivers 2002).*

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	3

- *The main requirement of this species is sufficient temperature, in which the Great Lakes is very dissimilar from native and introduced ranges of this species. The optimal growth temperature range for the plant is 22-30°C (72-86°F) (Kasselmann 1995).*
- *Rivers (2002) noted that for* P. stratiotes *to survive, it requires a wet, temperate habitat. It is usually found in lakes and rivers; however, it can also survive in mud.*
- Pistia stratiotes *can endure temperature extremes of 15°C (59°F) and 35°C (95F°). The optimal growth temperature range for the plant is 22-30°C (72-86°F) (Kasselmann 1995).*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	3

- *Pollution in the Great Lakes is similar to that where water lettuce is currently found; it thrives in ecologically disturbed habitats with high nutrient concentrations (Sharma 1984, Neuenschwander et al. 2009).*
- Pistia statiotes *is freshwater species that prefers still or slowly-moving waters, with no other major requirements asides from temperature (can endure temperature extremes of 15° C (59° F) and 35° C (95°)* (Kasselmann 1995).

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3

Scarce (Suitable habitats are rarely found)	0
Unknown	U
	1

- *It is unlikely to find habitat with suitable temperature for survival through winter (can only tolerate temperatures to 59°F). The optimal growth temperature range for the plant is 22-30° C (72-86° F) (Kasselmann 1995).*
- *However, this species has successfully over-wintered in a temperate climate zone in Slovenia (mean winter temperatures 0 to -3°C). There, it covered nearly the entire water body where thermal springs caused elevated temperatures. Thus, this species may persist in small populations where water temperature remains elevated (despite cold air temperatures), such as a discharges from power stations (Šajna et al. 2007).*
- *It is also unlikely to find habitat with suitable temperatures to provide sufficient time for seeds that have overwintered to germinate in time to permit the production of seeds during the second growing season (Cochran et al. 2006). Pieterse et al. (1981) indicated that seeds do not germinate until temperature exceeds 20°C. However, seeds can survive temperatures of -5°C (Pieterse et al. 1981).*
- *Otherwise, it inhabits slow moving waters in streams, rivers, lakes, ponds, and wet ditches and could find suitable habitat (Thompson 2000).*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0
Unknown	U
	8

- *Warmer air/water temperatures and/or less severe winters may allow for either over-wintering of adult plants or successive years of seed production (NCEA 2008, Hussner et al. 2010).*

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is moderate to high)	3

Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
	9

- *This species is an autotroph, with no specific nutrient requirements.*

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Great Lakes and is not likely to be introduced	-80% total points (at end)
Unknown	U
	9

- *No other species are critical.*

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes)	6
Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0

Unknown	U
	0

- *No facilitating species have been identified.*

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0
Unknown	U
	0

- *This species has not been controlled by any natural enemy in its introduced range, and no species exists in the Great Lakes that would be expected to control it.*

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9
Frequent, moderate inocula	6
Frequent, small inocula OR infrequent, large inocula	3
Infrequent, small or moderate inocula	0
Unknown	U
	7

- *Given the widespread availability of this plant for purchase, lack of regulations, and the repeated introduction events (e.g., in the Detroit River and Lake St Clair, Eyraud and MacIsaac 2013) this plant has had frequent inoculations. Also, given the vegetative reproduction, even a small population of this plant could be considered moderate.*

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
	9

- *This species has spread to every continent except Antarctica (alleged native of South America) (Cordo et al. 1981).*
- *This species has invaded over 40 countries (Holm 1991).*

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
	7

- *This species shows explosive growth in suitable habitats (e.g., can cover a lake 700 m x 135 m in single year) (Sridhar and Sharma 1980, Venema 2001).*
- *Rapid vegetative reproduction allows water lettuce to cover an entire lake, from shore to shore, with a dense mat of connected rosettes in a short period of time. In Florida, water lettuce has been known to have densities of up to 1,000 rosettes per m^2 (Rivers 2002).*

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing the establishment and spread of this species)	-90% total points (at end)
Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control	-20% total points (at

its establishment and spread)	end)
No control methods have been set to prevent the establishment and/or spread of this species	0
Unknown	U
	-30%

- *This species is not regulated in any way and is still sold throughout the Great Lakes.*
- *Surveillance and management efforts are currently underway to detect, control and/or eradicate this plant in Michigan (MI DEQ 2013) and Wisconsin (Falck et al. 2010). However, a basin-wide monitoring program is lacking (Dupre 2011).*

Establishment Potential Scorecard				
Points	**Probability for Establishment**	A. Total Points (pre-adjustment)		83
>100	High	**Adjustments**		
		B. Critical species	A*(1- 0%)	83
51-99	Moderate	C. Natural enemy	B*(1- 0%)	83
		Control measures	C*(1- 30%)	58.1
0-50	Low	**Potential for Establishment**		Moderate
# of questions answered as "unable to determine"	**Confidence Level**			
0-1	High	Total # of questions unknown		0
2-5	Moderate			
6-9	Low	Confidence Level		High
>9	Very low			

Section C: Potential for Impact

IMPACT POTENTIAL RESULTS

Environmental: High

Socio-Economic: High

Beneficial: Moderate

***Pistia stratiotes* has the potential for high environmental impact if introduced to the Great Lakes.**

Pistia stratiotes may have detrimental impacts on other species and the environment. *Pistia stratiotes* produces α-asarone, a phenylpropanoid with antialgal activity (Aliotta et al. 1991), so it may interfere with the growth processes in algae. *Pistia stratiotes* causes high evapotranspiration rates where it occurs (Sharma 1984). By growing in dense mats, *P. stratiotes* can shade out and reduce the amount of light available to submerged macrophytes and planktonic algae (Attionu 1976). In addition, its dense cover may reduce water temperature, reduce pH, promote stratification, and inhibit mixing of the water by wind (Attionu 1976). As a result of its inhibition of hydrophyte and algal growth, the respiratory activity of its roots, decomposition when it dies, and the restriction of wind-generated mixing, *P. stratiotes* can reduce the amount of dissolved oxygen where it occurs (Attionu 1976, Šajna et al. 2007, Sridhar and Sharma 1985). It is suspected that the oxygen and light limitations caused by *P. stratiotes* may have killed native plants, fish, and wildlife (FDEP 2007). Three years after *P. stratiotes* was first observed in Slovenia, there was a decline in native freshwater plants (*Ceratophyllum demersum*, *Myriophyllum spicatum*, *Najas marina*, and *Trapa natans*) (Šajna et al. 2007).

***Pistia stratiotes* has the potential for high socio-economic impact if introduced to the Great Lakes.**

Pistia stratiotes is among the world's worst weeds (Holm 1991) and has received significant media attention (de la Cruz 2014, Spear 2014).

Pistia stratiotes mats provide habitat for disease carrying mosquitos, such as malaria vectors *Anopheles* and *Mansonia* (FDEP 2007, Lounibos and Dewald 1989, Parsons and Cuthbertson 2001, Rejmankova et al. 1991). *Mansonia* larvae perforate leaves and roots of *P. stratiotes* to reach air chambers (Lounibos and Dewald 1989). *Taeniorhynchus* (*Mansonioides*) *africanus* and *Anopheles gambiae* breed in ponds and streams that are clogged with *P. stratiotes* (Philip 1930).

Pistia stratiotes causes damages to infrastructure. Infestations of this species can block waterways, reducing the efficiency of irrigation and hydroelectric power (Howard and Harley 1997). Dense mats of *P. straiotes* reduce water flow, damages flood control structures, and can create dams against bridges (FDEP 2007). *Pistia stratiotes* may impact recreation, as it interferes with navigation and fishing (Labrada and Fornasari 2002). Florida spent about $1.4 million dollars in 2005-2006 to treat *P. stratiotes* (FDEP 2007).

***Pistia stratiotes* has the potential for moderate beneficial impact if introduced to the Great Lakes.**

This plant has the fiber content, carbohydrate, and crude protein levels that are comparable with quality forages (Parsons and Cuthbertson 2001). This plant can be fed to pigs, but cows find it unpalatable. *Pistia stratiotes* is valued as an ornamental plant in water gardens. Research has been conducted to utilize this species for biofuels and water remediation (Lu et al. 2010, Mishima et al. 2008). *Pistia stratiotes* is used in Ayurvedic medicine for its diuretic, antidiabetic, and antidermatophytic, antifungal and antimicrobial properties.

POTENTIAL ENVIRONMENTAL IMPACT

NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6

Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1 √
Not significantly	0
Unknown	U

- Pistia stratiotes *produces α-asarone, a phenylpropanoid with antialgal activity that interferes with growth processes in plants (Aliotta et al. 1991).*

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6 √
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1
Not significantly	0
Unknown	U

- *Mats of* P. stratiotes *reduce or eliminate light for submerged hydrophytes, epiphytic, and planktonic algae (Attionu 1976).*
- *In Slovenia, as early as three years after the first observation of* P. stratiotes*, native freshwater plants (*Ceratophyllum demersum *L.,* Myriophyllum spicatum *L.,* Najas marina *L., and* Trapa natans *L.) declined in a species-rich wetland habitat because the whole water surface was covered with a dense mat that remained closed even during the winter (Šajna et al. 2007).*
- *Oxygen and light limitations caused by* P. stratiotes *killed native plants, fish and wildlife (Chokder 1968, FDEP 2007).*

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in the food web)	6
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	1
Not significantly	0 √
Unknown	U

- *This species has not been documented to be involved in predator-prey relationships.*

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the	1

individual level	
Not significantly	0 √
Unknown	U

- *No genetic effects have been observed.*

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6 √
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1
Not significantly	0
Unknown	U

- *As a result of poor hydrophytic and algal growth, the respiratory activity of its roots, the decay of dead plants and restriction of wind-generated mixing, dissolved oxygen became markedly depleted and the water more acidic at sites with dense mats of* Pistia stratiotes *(Attionu 1976, Sridhar and Sharma 1985). Two sites with dense mats were included in the Attionu (1976) study:*
    - *Dissolved oxygen levels of water immediately under mats were about half the DO levels of water in open water areas, in both October and January at both dense sites (Attionu 1976).*
    - *Oxygen profiles showed dissolved oxygen around 5% saturation at 10 m and 0% saturation at 20 m under* Pistia stratiotes *mats on River Dayi (Figure 2) (Attionu 1976).*
    - *Oxygen profiles showed dissolved oxygen around 15% saturation at 1 m and 0% saturation at 9 m under* Pistia stratiotes *mats on River Pawnpawm (Figure 3) (Attionu 1976).*
    - *Mean pH of water was measured at two times of the year at River Dayi: mean pH under mats was 6.1, and mean pH in open water areas was 7 in October; mean pH of water under mats was 6.4, and mean pH in open water areas was 8.2 in January (Attionu 1976).*
    - *Mean pH of water under mats was measured at one time of the year at River Pawnpawm: mean pH under mats was 6.9, and mean pH in open water areas was 7.4 in November (Attionu 1976).*
- *Dissolved oxygen values declined by more than 50% when measured under the* P. stratiotes *cover, reaching only 2.5 mg/L, a critical value for fish survival (Šajna et al. 2007).*
- *Chemical control measures (diquat and carfentrazone) used for* Pistia stratiotes *also impact water quality (FDEP 2007).*

E6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1 √
Not significantly	0
Unknown	U

- Pistia stratiotes *alters the physio-chemical condition of substrate (Attionu 1976).*

- *Evapotranspiration rates with* Pistia stratiotes *are 8-17x greater than evaporation rates (without* Pistia*) (Sharma 1984).*
- Pistia stratiotes *increased sedimentation by shredding roots and shoots (FDEP 2007).*

Environmental Impact Total	**14**
Total Unknowns (U)	**0**

Scoring		
Score	# U	**Impact**
>5	Any	**<u>High</u>**
2-5	Any	Moderate
0	0-1	Low
1	0	
0	≥2	Unknown
1	≥1	

<u>POTENTIAL SOCIO-ECONOMIC IMPACT</u>

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6 √
Yes, but negative consequences have not been widespread, long lasting, or severe	1
Not significantly	0
Unknown	U

- Pistia stratiotes *can also harbor disease-carrying mosquitoes such as species of the malaria vectors* Anopheles *and* Mansonia *(Lounibos and Dewald 1989, Rejmankova et al. 1991). The larvae of* Mansonia *perforate leaves and roots of* P. stratiotes *to reach air chambers (Lounibos and Dewald 1989).*
- Taeniorhynchus (Mansonioides) africanus*, Théo., and* Anopheles gambiae*, Giles (costalis, Theo.) mosquitoes breed in ponds and even in streams that become clogged during low water with abundant growths of water lettuce (*Pistia stratiotes*), to which the immature stages attach themselves for purposes of respiration (Philip 1930).*
- Pistia stratiotes *is responsible for "forming dense aggregations of free floating vegetation, known as suds, which in swampy areas have claimed many lives in the Sudan" (Sridhar and Sharma 1980).*

S2) Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6 √
Yes, but the costs have been small and are largely reparable or preventable	1
Not significantly	0
Unknown	U

- Pistia stratiotes *restricts water flow in irrigation and flood control canals (OMNR 2010).*
- Pistia stratiotes *creates dams against bridges and reduces water flow at flood control structures (FDEP 2007).*
- *Reports mention impacts of this type that occur (but are not quantified) throughout water bodies in Africa (Sridhar and Sharma 1980, Holm 1991).*

S3) Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0 √
Unknown	U

- *There are no reports of this.*

S4) Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6 √
Some damage to markets or sectors has been observed, but negative consequences have been small	1
Not significantly	0
Unknown	U

- *Waterways can be blocked, and the efficiency of irrigation (agriculture) and hydro generation (energy) impaired (Howard and Harley 1997).*
- Pistia stratiotes *clogs rivers and canals, interferes with the activity of hydroelectric power stations, hampers fishing, hampers navigation, and negatively affects water control and use for agricultural purposes (Labrada and Fornasari 2002).*
- *From 2005-2006, treatment of* P. stratiotes *in Florida water cost about $1.4 million dollars (40% of 3.5 million dollars) (FDEP 2007).*
- Pistia stratiotes *can invade rice fields, severely limiting the growth of this crop (Sculthorpe 1985).*

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6 √
Yes, but negative consequences have been small	1
Not significantly	0
Unknown	U

- *People are affected by reduction of the fish catch, inability to travel by boat, and consequent isolation from gardens, markets, and health services caused by* P. stratiotes *(Howard and Harley 1997).*

- Pistia stratiotes *clogs waterways, making boating, fishing, and almost all other water activities difficult if not impossible.*

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6 √
Yes, but negative consequences have been small	1
Not significantly	0
Unknown	U

- Pistia stratiotes *is one of the world's worst weeds (Holm 1991), with significant media attention. While there has been no formal study of this indirect value (aesthetic/natural), the dense and unavoidable mats would certainly impact these values. Evidence of the undesirable nature of this plant is seen in the money spent to control it.*

Socio-Economic Impact Total	**30**
Total Unknowns (U)	**0**

Scoring		
Score	# U	**Impact**
>5	Any	**<u>High</u>**
2-5	Any	Moderate
0	0-1	Low
1	0	Low
0	≥2	Unknown
1	≥1	Unknown

<u>POTENTIAL BENEFICIAL EFFECT</u>

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular effect. An "Unknown" response is appropriate if the potential for a particular effect might be inferred but has not been explicitly reported or if there is an unresolved debate about a particular effect.

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1
Not significantly	0 √

Unknown	U

- *No indication of this was found.*

B2) Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?

Yes, it is economically important to at least one of these industries	6
Yes, but its economic contribution is small	1 √
Not significantly	0
Unknown	U

- Pistia stratiotes *is sold in the ornamental trade.*
- *The ethanol yield per unit biomass from water lettuce was comparable to those from other agricultural wastes. It was concluded that aquatic plants are a promising biomass for ethanol production when the fermentation process is fully optimized (Mishima et al. 2008).*

B3) Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local communities and/or tourism	6
It is sometimes employed recreationally, but adds little value to local communities or tourism	1 √
Not significantly	0
Unknown	U

- *This species is planted in water gardens.*

B4) Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR It is potentially important to medicine or research and is currently being or scheduled to be studied	1 √
Not significantly	0
Unknown	U

- Pistia stratiotes *is commonly used in Ayurvedic medicine (diuretic, antidiabetic, antidermatophytic, antifungal, and antimicrobial properties).*

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1 √
Not significantly	0
Unknown	U

- Pistia stratiotes *is a potential candidate for the removal of Zn, Cr, Cu, Cd, Pb, Ag, and Hg. The plant could be used to treat water containing low concentrations of these elements (Odjegba and Fasidi 2004).*
- Pistia stratiotes *could be used to remediate runoff (which often contains soluble nitrates and phosphates and heavy metal trace elements) from nursery and greenhouse operations (Sridhar and Sharma 1980, Polomski et al. 2009).*

B6) Does the species have a positive ecological effect outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1
Not significantly	0 √
Unknown	U

- *No additional positive effects were found.*

Beneficial Effect Total	**4**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	**Moderate**
0	0-1	Low
1	0	
0	≥2	Unknown
1	≥1	

Scientific Name: *Stratiotes aloides* Linnaeus

Common Name: Water Soldier, Water Pineapple

Synonyms:

Section A: Potential for Introduction

INTRODUCTION POTENTIAL RESULTS

Dispersal: High

Hitchhiking/fouling: High

Unauthorized intentional release: Low

Stocking/planting/escape from recreational culture: High

Escape from commercial culture: Unlikely

Transoceanic shipping: Unlikely

***Stratiotes aloides* has a high probability of introduction to the Great Lakes (Confidence level: High).**

Potential pathway(s) of introduction: Dispersal, Hitchhiking/Fouling, Stocking/Planting/Escape from Recreational Culture

Stratiotes aloides was listed by the Great Lakes Governors and the Premiers of Ontario and Québec as a "least wanted" aquatic invasive species in the Great Lakes. Water soldier crowds out native vegetation resulting in decreased plant biodiversity. Dense floating mats hinder boating, angling and swimming, and sharp serrated leaf edges can cut swimmers.

POTENTIAL INTRODUCTION VIA DISPERSAL

1a) Does this species occur near waters (natural or artificial) connected to the Great Lakes basin* (e.g., streams, ponds, canals, or wetlands)? (*Great Lakes basin = below the ordinary high water mark, including connecting channels, wetlands, and waters ordinarily attached to the Lakes)

Yes, this species occurs near waters connected to the Great Lakes basin and is mobile or able to be transported by wind or water.	100 √
No, this species does not occur near waters connected to the Great Lakes basin and/or is not mobile or able to be transported by wind or water.	0
Unknown	U

- *This species occurs in the Trent River, Ontario, with a population of over 22,000 plants (Campbell 2009).*

1b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 kilometers of the Great Lakes basin, and no barrier (e.g., electric barrier, dam) to dispersal is present.	Score x 1 √
This species occurs in waters within 20 kilometers of the Great Lakes basin, but dispersal to the basin is blocked; or, this species occurs in waters within 100 kilometers of the Great Lakes basin, and no barrier to dispersal is present.	Score x 0.75
This species occurs in waters within 100 kilometers of the Great Lakes basin, but dispersal to the basin is blocked.	Score x 0.5
This species occurs in waters >100 kilometers from the Great Lakes basin.	Score x 0.25
Unknown	U

- *This species occurs at 44.382919 N, 77.840845 W, in the Trent River near Nappan Island, Ontario (OMNR 2013).*

POTENTIAL INTRODUCTION VIA HITCHHIKING/FOULING

2a) Is this species likely to attach to or be otherwise transported by, or along with, recreational gear, boats, trailers, fauna (e.g., waterfowl, fish, insects), flora (e.g., aquatic plants), or other objects (e.g., packing materials), including as parasites or pathogens, entering the Great Lakes basin?

Yes, this species is known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	100 √
No, this species is not known to be able to adhere to certain surfaces or to be transported by other organisms entering the Great Lakes basin.	0
Unknown	U

- *Aquatic macrophytes are commonly found on trailered boats, and the Trent-Severn waterway is a popular destination for boaters (thewaterway.ca).*

2b) What is the proximity of this species to the Great Lakes basin?

This species occurs in waters within 20 km of the Great Lakes basin.	Score x 1 √
This species occurs in waters within 100 km of the Great Lakes basin.	Score x 0.5
This species occurs in waters >100 km from the Great Lakes basin.	Score x 0.1
Unknown	U

- *This species occurs at 44.382919 N, 77.840845 W, in the Trent River near Nappan Island, Ontario (OMNR 2013).*

POTENTIAL INTRODUCTION VIA UNAUTHORIZED INTENTIONAL RELEASE

3a) Is this species sold at aquarium/pet/garden stores ("brick & mortar" or online), catalogs, biological supply companies, or live markets (e.g., purchased for human consumption, bait, ornamental, ethical, educational, or cultural reasons) and as a result may be released into the Great Lakes basin?

Yes, this species is available for purchase.	100 √
No, this species this species is rarely/never sold.	0
Unknown	U

- *As of June 2012, this species is only prohibited in Illinois and Minnesota.*

- *It is commonly used in water ponds/gardens (OMNR 2009)*

3b) How easily is this species obtained within the Great Lakes region (states/provinces)?

This species is widely popular, frequently sold, and/or easily obtained within the Great Lakes region.	Score x 1
This species is widely popular, and although trade, sale, and/or possession of this species is prohibited, it is frequently sold on the black market within the Great Lakes region.	Score x 0.5
This species is not very popular or is not easily obtained within the Great Lakes region.	Score x 0.1 √
Unknown	U

- *This species was hard to find using online searches, but literature has described it as occurring in 10% of Ontario stores (Funnell et al. 2009)*

POTENTIAL INTRODUCTION VIA STOCKING/PLANTING OR ESCAPE FROM RECREATIONAL CULTURE

4a) Is this species being stocked/planted to natural waters or outdoor water gardens around the Great Lakes region?

Yes, this species is being stocked/planted and/or has ornamental, cultural, medicinal, environmental (e.g., biocontrol, erosion control), scientific, or recreational value in the Great Lakes region.	100 √
No, this species cannot be stocked/planted or there is not enough interest to do so in the Great Lakes region.	0
Unknown	U

- *The infestation in the Trent River began as an accidental escape (OMNR 2009).*

4b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is authorized and/or is occurring directly in the Great Lakes.	Score x 1 √
This activity is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is likely to occur within 20 km of the Great Lakes basin because of its popularity/value and there are no widespread regulations against stocking/planting.	Score x 0.5
This activity is occurring in waters >20 km from the Great Lakes basin, or despite federal or state regulations in more than half the basin (> 5 states/provinces), this activity may occur within 20 km of the basin because of the species' popularity/value.	Score x 0.25
Unknown	U

- *This species occurs at 44.382919 N, 77.840845 W, in the Trent River near Nappan Island, Ontario (OMNR 2013).*

POTENTIAL INTRODUCTION VIA ESCAPE FROM COMMERCIAL CULTURE

5a) Is this species known to be commercially cultured in or transported through the Great Lakes region?

Yes, this species is being commercially cultured in or transported through the Great Lakes region.	100
No, this species is not commercially cultured in or transported through the Great Lakes region.	0 √
Unknown	U

5b) What is the nature and proximity of this activity to the Great Lakes basin?

This activity is unregulated or minimally regulated and is occurring directly in the Great Lakes.	Score x 1
This activity is unregulated or minimally regulated and is occurring in Great Lakes tributaries or connecting waters, or within 20 km of the Great Lakes basin.	Score x 0.75
This activity is strictly regulated but occurs directly in the Great Lakes, and/or this activity involves transport of live organisms on/across the Great Lakes.	Score x 0.5
This activity is strictly regulated but occurs in Great Lakes tributaries, connecting waters, or within 20 km of the Great Lakes basin, and/or this activity involves transport of live organisms within 20 km of the Great Lakes basin.	Score x 0.25
This activity occurs >20 km from the Great Lakes basin and typically does not involve transport of live organisms closer to the basin.	Score x 0.1
Unknown	U

POTENTIAL INTRODUCTION VIA SHIPPING

6a) Is this species likely to be taken up in ballast, and capable of surviving adverse environments (i.e. extreme temperatures, absence of light, low oxygen levels) and partial-to-complete ballast water exchange/flushing (e.g., is euryhaline, buries in sediment, produces resistant resting stages, has other attributes or behaviors facilitating survival under these conditions)?

Yes, this species is able to survive in ballast tank environments for weeks at a time and is not substantially impacted by current regulatory requirements (e.g., exchange, flushing).	100
Yes, this species is able to survive in ballast tank environments for weeks at a time, but survival is substantially impacted by current regulatory requirements.	80
No, but this species is capable of fouling transoceanic ship structures (e.g., hull, chains, chain locker) while in its active or resting stage.	40
No, this species is unlikely to be taken up in ballast, not able to survive adverse environments, does not foul transoceanic ship structures, or is unable to survive current ballast water regulations.	0 √
Unknown	U

6b) Does this species occur in waters from which shipping traffic to the Great Lakes originates?

Yes, and this species has been observed in ballast of or fouling ships entering the Great Lakes.	Score x 1
Yes, and this species has been observed in ports that have direct trade connections with the Great Lakes (e.g., Baltic Sea).	Score x 0.5

Yes, but this species has neither been observed in ballast/fouling ships entering the Great Lakes nor in ports in direct trade with the Great Lakes.	Score x 0.1
No, this species does not occur in waters from which shipping traffic to the Great Lakes originates.	Score x 0
Unknown	U

Vector Potential Scorecard				
Vector	**Raw Points Scored**	**Proximity Multiplier**	**Total Points Scored**	**Probability of Introduction**
Dispersal: Natural dispersal through waterbody connections or wind	**100**	x 1	**100**	High
Hitchhiking/fouling: Transport via recreational gear, boats, trailers, mobile fauna, stocked/planted organisms, packing materials, host organisms, etc.	**100**	x 1	**100**	High
Release: Unauthorized intentional release of organisms in trade (e.g., aquaria, water gardens, live food)	**100**	x 0.1	**10**	Low
Stocking/planting/escape from recreational culture: Intentional authorized or unauthorized introduction to natural waters in the Great Lakes OR Accidental introduction to Great Lakes by escape from recreational culture (e.g., water gardens)	**100**	x 1	**100**	High
Escape from commercial culture: Accidental introduction to Great Lakes by escape from commercial culture (e.g., aquaculture)	**0**	x	**0**	Unlikely
Transoceanic shipping: Ballast (BOB) or no-ballast-on-board (NOBOB) water exchange/discharge, sediment discharge, hull fouling	**0**	x	**0**	Unlikely
Total Unknowns (U) **0**		**Confidence Level**	High	

Scoring	
Points (per vector)	**Probability for Introduction**
80-100	High
40-79	Moderate
1-39	Low
0	Unlikely
# of Unknowns (overall)	**Confidence Level**
0	High
1-2	Moderate
3-5	Low
>5	Very low

Section B: Potential for Establishment

ESTABLISHMENT POTENTIAL RESULTS

Status: Established in North America, but not the Great Lakes

***Stratiotes aloides* has a moderate probability of establishment if introduced to the Great Lakes (Confidence level: High).**

Stratiotes aloides has been described by government agencies as likely to crowd out native vegetation (OMNR 2009), though no primary literature exists to support this in introduced habitats. It does form "dense, almost monospecific stands" in native habitat (Strzałek and Koperski 2009). Most species in the genus produce vegetative fragments and reproduce easily. *Stratiotes aloides* can overwinter in the Great Lakes; the population in Finland overwinters fine in temperatures similar to those experienced in the Great Lakes.

INVASIVE BIOLOGICAL/ECOLOGICAL ATTRIBUTES

1) How would the physiological tolerance of this species (survival in varying temperature, salinity, oxygen, and nutrient levels) be described?

This species has broad physiological tolerance. It has been reported to survive in wide ranges of temperature (0°C-30°C), salinity (0-16 parts per thousand), oxygen (0-saturated), AND nutrient (oligotrophic-eutrophic) levels.	9
This species has somewhat broad physiological tolerance. It has been reported to survive in a wide range of temperature, salinity, oxygen, OR nutrient levels. Tolerance to other factors is narrower, unknown, or unreported.	6
This species has narrow physiological tolerance. It has been reported to survive in limited ranges of temperature, salinity, oxygen, and nutrient levels.	3
Unknown	U
	6

- *This species is native from the United Kingdom through to Asia. Specifically, the United Kingdom, Spain, Italy, Bulgaria and Siberia (Natural History Museum of London 2013). It ranges as far north as Kittila, Finland (Kittila is located at 67°N) (Natural History Museum of London 2013).*
- *This species is limited to freshwater.*

2) How likely is it that any life stage of this species can overwinter in the Great Lakes (survive extremely low levels of oxygen, light, and temperature)?

Likely (This species is able to tolerate temperatures under 5°C and oxygen levels ≤0.5 mg/L)	9
Somewhat likely (This species is able to tolerate some of these conditions OR has adapted behaviorally to avoid them)	6
Somewhat unlikely (This species is able to tolerate conditions close to those specified, but it is not known as an overwintering species)	3
Unlikely	0

Unknown	U
	9

- *As this species ranges as far north as Kittila, Finland (Kittila is located at 67°N), where the coldest temperatures in Finland occur, it will likely overwinter in the Great Lakes as well.*

3) If this species is a heterotroph, how would the flexibility of its diet be described?

This species is a dietary generalist with a broad, assorted, AND flexible diet.	9
This species is moderately a dietary generalist with a broad, assorted, OR flexible diet.	6
This species is a dietary specialist with a limited and inflexible diet.	3
This species is an autotroph.	0
Unknown	U
	0

- *This species is an autotroph*

4) How likely is this species to outcompete species in the Great Lakes for available resources?

Likely (This species is known to have superior competitive abilities and has a history of outcompeting other species, AND/OR available literature predicts it might outcompete native species in the Great Lakes)	9
Somewhat likely (This species is known to have superior competitive abilities, but there are few reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	6
Somewhat unlikely (This species has average competitive abilities, and there are no reported cases of this species outcompeting another and no predictions regarding species in the Great Lakes)	3
Unlikely (This species is known as a poor competitor that thrives only in environments with low biodiversity, AND/OR available literature predicts it might be outcompeted by a species in the Great Lakes)	0
Unknown	U
	7

- *This species has been described by government agencies as likely to crowd out native vegetation (OMNR 2009), though no primary literature exists to support this in introduced habitats. It does form "dense, almost monospecific stands" in native habitat (Strzałek and Koperski 2009).*

5) How would the fecundity of this species be described relative to other species in the same taxonomic Class?

Very high	9
High	6
Moderate	3

Low	0
Unknown	U
	3

- *Most species in the genus produce vegetative fragments.*

6) How likely are this species' reproductive strategy and habits to aid establishment in new environments, particularly the Great Lakes (e.g., parthenogenesis/self-crossing, self fertility, vegetative fragmentation)?

Likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, AND available literature predicts establishment in the Great Lakes based on these attributes)	9
Somewhat likely (The reproductive strategy or habits of this species are known to aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	6
Somewhat unlikely (The reproductive strategy or habits of this species could potentially aid establishment in new environments, but there is no literature available regarding establishment in the Great Lakes based on these attributes)	3
Unlikely (The reproductive strategy or habits of this species are not known to aid establishment in new environments)	0
Unknown	U
	9

- *This species has vegetative reproduction. Vegetative propagules are formed as axillary buds. When the bottom leaves of the rosette decay, these buds are released. On average 4.7 (±0.28 SE) buds are formed per mature rosette (n = 83) (Sarneel 2013). Buds have high capacity to disperse over long distances via water (84% of propagules re-sprouted, and 92% were still floating after 187 days) (Sarneel 2013).*
- *This species has survived and spread in the Great Lakes area (Trent River) for several years.*

ENVIRONMENTAL COMPATIBILITY

7) How similar are the climatic conditions (e.g., air temperature, precipitation, seasonality) in the native and introduced ranges of this species to those in the Great Lakes region?

Very similar (The climatic conditions are practically identical to those of the Great Lakes region)	9
Similar (Many of the climatic conditions are similar to those of the Great Lakes region)	6
Somewhat similar (Few of the climatic conditions are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	9

- *This species is native from the United Kingdom through to Asia. Specifically, the United Kingdom, Spain, Italy, Bulgaria and Siberia (Natural History Museum of London 2013). It ranges as far north as Kittila, Finland (Kittila is located at 67°N) (Natural History Museum of London 2013). Given this broad range, the climatic conditions are likely favorable in the Great Lakes.*

8) How similar are other abiotic factors that are relevant to the establishment success of this species (e.g., pollution, water temperature, salinity, pH, nutrient levels, currents) in the native and introduced ranges to those in the Great Lakes?

Very similar (These factors are practically identical to those of the Great Lakes region)	9
Similar (Many of these factors are similar to those of the Great Lakes region)	6
Somewhat similar (Few of these factors are similar to those of the Great Lakes region)	3
Not similar	0
Unknown	U
	6

- *This species usually inhabits shallow stagnant waters, mainly eutrophic and mesotrophic, with substratum of mud and organic deposits (Strzałek and Koperski 2009).*

9) How abundant are habitats suitable for the survival, development, and reproduction of this species in the Great Lakes area (e.g., those with adequate depth, substrate, light, temperature, oxygen)?

Abundant (Suitable habitats can be easily found and readily available)	9
Somewhat abundant (Suitable habitats can be easily found but are in high demand by species already present)	6
Somewhat scarce (Suitable habitats can be found occasionally)	3
Scarce (Suitable habitats are rarely found)	0
Unknown	U
	7

- *This species can grow in depths of up to 6.5m (Tarkowska-Kukuryk 2006).*
- *Stratiotes aloides is found mainly in sheltered bays of larger lakes, backwater ponds, ditches and canals (Natural History Museum of London 2013).*
- *This species usually inhabits shallow stagnant waters, mainly eutrophic and mesotrophic, with substratum of mud and organic deposits (Strzałek and Koperski 2009).*

10) How likely is this species to adapt to or to benefit from the predicted effects of climate change on the Great Lakes freshwater ecosystems (e.g., warmer water temperatures, shorter duration of ice cover, altered streamflow patterns, increased salinization)?

Likely (Most of the effects described above make the Great Lakes a better environment for establishment and spread of this species OR this species could easily adapt to these changes due to its wide environmental tolerances)	9
Somewhat likely (Several of the effects described above could make the Great Lakes a better environment for establishment and spread of this species)	6
Somewhat unlikely (Few of the effects described above would make the Great Lakes a better environment for establishment and spread of this species)	3
Unlikely (Most of the effects described above would have no effect on establishment and spread of this species or would make the environment of the Great Lakes unsuitable)	0

Unknown	U
	3

- *This species overwinters well in very cold climates, so climate change should confer so real advantage.*

11) How likely is this species to find an appropriate food source (prey or vegetation in the case of predators and herbivores, or sufficient light or nutrients in the case of autotrophs)?

Likely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are highly abundant and/or easily found)	9
Somewhat likely (Some nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is low to moderate)	6
Somewhat unlikely (Few nutritive food items—including species in the Great Lakes that may be considered potential food items—are abundant and/or search time is moderate to high)	3
Unlikely (All possible nutritive food items—including species in the Great Lakes that may be considered potential food items—are relatively scarce and/or search time is high)	0
Unknown	U
	9

- *This species survives in temperature climate, so sunlight in Great Lakes should be sufficient.*

12) Does this species require another species for critical stages in its life cycle such as growth (e.g., root symbionts), reproduction (e.g., pollinators, egg incubators), spread (e.g., seed dispersers), or transmission (e.g., vectors)?

Yes, and the critical species (or one that may provide a similar function) is common in the Great Lakes and can be easily found in environments suitable for the species being assessed; OR, No, there is no critical species required by the species being assessed	9
Yes, and the critical species (or one that may provide a similar function) is moderately abundant and relatively easily found in particular parts of the Great Lakes	6
Yes, and the critical species (or one that may provide a similar function) is relatively rare in the Great Lakes AND/OR can only be found occasionally in environments suitable for the species being assessed	3
Yes, and the critical species (or one that may provide a similar function) is not present in the Great Lakes but is likely to be introduced	0
Yes, but the critical species (or one that may provide a similar function) is not present in the Great Lakes and is not likely to be introduced	-80% total points (at end)
Unknown	U
	9

13) How likely is the establishment of this species to be aided by the establishment and spread of another species already in the Great Lakes?

Likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes, AND available literature predicts this previous invader might promote the establishment of this species, AND/OR there have been cases reported of this species aiding the establishment of this species in other areas)	9
Somewhat likely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established and spread in the Great Lakes)	6
Somewhat unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species—a major host, food item, pollinator—has already established in the Great Lakes BUT it is still confined to a small area of the Lakes and the likelihood of encounter with this species assessed is hard to predict)	3
Unlikely (A non-indigenous species to the Great Lakes that facilitates the development of this species has not been established in the Great Lakes)	0
Unknown	U
	0

14) How likely is establishment of this species to be prevented by the herbivory, predation, or parasitism of a natural enemy this is already present in the Great Lakes and may preferentially target this species?

Likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is well documented in the literature AND this natural enemy is abundant and widespread in the Great Lakes)	-80% total points (at end)
Somewhat likely (The ability of the natural enemy to prevent the establishment of this species in introduced ranges or limiting populations of this species in native ranges is suggested in the literature OR this natural enemy has limited distribution in the Great Lakes)	-60% total points (at end)
Somewhat unlikely (There are few cases reported of such a natural enemy preventing the establishment of this species in introduced ranges or limiting populations of this species in native ranges OR this natural enemy has low abundance in the Great Lakes)	-10% total points (at end)
Unlikely (Such a natural enemy is particularly rare or is not present in the Great Lakes)	0
Unknown	U
	0

PROPAGULE PRESSURE

15) On average, how large and frequent are inoculations (introduction events) from the potential vectors identified in Section A for this species? (What is the total number of individuals introduced?)

Frequent, large inocula	9

Frequent, moderate inocula	6
Frequent, small inocula OR infrequent, large inocula	3
Infrequent, small or moderate inocula	0
Unknown	U
	0

- *Release or escape from recreational culture is generally infrequent, and would likely be limited to a few plants.*

HISTORY OF INVASION AND SPREAD

16) How extensively has this species established reproducing populations in areas outside its native range as a direct or indirect result of human activities?

Very extensively (many invasive populations of this species have been reported in areas widely distributed from the native range)	9
Extensively (some invasive populations of this species have been reported in areas widely distributed from the native range)	6
Somewhat extensively (few invasive populations of this species have been reported in areas widely distributed from the native range OR all invasive populations are in close proximity to each other)	3
Not extensively (no invasive populations of this species have been reported)	0
Unknown	U
	1

- *The only invasive population reported has been in Ontario.*

17) How rapidly has this species spread by natural means or by human activities once introduced to other locations?

Rapidly (This species has a history of rapid spread in introduced ranges)	9
Somewhat rapidly (This species has a history of moderately rapid spread in introduced ranges)	6
Somewhat slowly (This species has a history of moderately slow spread in its introduced ranges)	3
Slowly (This species has a history of slow to no spread in its introduced ranges)	0
Unknown	U
	6

- *What would have likely started from a few plants has grown to 22,000 plants in seven populations.*

18) Are there any existing control measures in the Great Lakes set to prevent the establishment and/or spread of this species?

Yes, and they are likely to prevent establishment or spread of the species. (There are no reported cases of this species adapting or avoiding current measures. These measures are highly effective in preventing the establishment and spread of this species)	-90% total points (at end)

Yes, and they are moderately likely to prevent establishment or spread of the species. (There are few reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-50% total points (at end)
Yes, but they are unlikely to prevent establishment or spread of the species. (There are many reported cases of this species adapting or avoiding current measures used to control its establishment and spread)	-20% total points (at end)
No control methods have been set to prevent the establishment and/or spread of this species	0
Unknown	U
	0

Establishment Potential Scorecard				
Points	**Probability for Establishment**	A. Total Points (pre-adjustment)		84
>100	High	**Adjustments**		
		B. Critical species	A*(1- 0%)	84
51-99	Moderate	C. Natural enemy	B*(1- 0%)	84
		Control measures	C*(1- 0%)	84
0-50	Low	**Potential for Establishment**		Moderate
# of questions answered as "unable to determine"	**Confidence Level**			
0-1	High	Total # of questions unknown		0
2-5	Moderate			
6-9	Low	Confidence Level		High
>9	Very low			

Section C: Potential for Impact

IMPACT POTENTIAL RESULTS

Environmental: Moderate

Socio-Economic: Moderate

Beneficial: Low

***Stratiotes aloides* has the potential for moderate environmental impact if introduced to the Great Lakes.**

Stratiotes aloides forms "dense, almost monospecific stands" in native habitat (Strzałek and Koperski 2009) and has the potential to crowd out native vegetation (OMNR 2009).

Stratiotes aloides has the potential to alter surrounding water chemistry, which may harm phytoplankton and other aquatic organisms (OMNR 2009). The exact mechanism has not been elucidated, but the likely cause is allelopathy (Mulderij et al. 2006).

***Stratiotes aloides* has the potential for moderate socio-economic impact if introduced to the Great Lakes.**
*Stratiotes aloides'*s sharp leaves can cut skin (Campbell 2009). Dense floating mats of water soldier can hinder recreational activities, such as boating, angling, and swimming. This would likely result from a massive infestation, but has not been quantified.

There is little or no evidence to support that *Stratiotes aloides* has the potential for significant beneficial impacts if introduced to the Great Lakes.
It has not been indicated that *Stratiotes aloides* can be used for the control of other organisms or improving water quality. There is no evidence to suggest that this species is commercially, recreationally, or medically valuable. It does not have significant positive ecological impacts.

POTENTIAL ENVIRONMENTAL IMPACT

NOTE: In this section, a "Not significantly" response should be selected if the species has been studied but there have been no reports of a particular impact. An "Unknown" response is appropriate if the species is poorly studied.

E1) Does the species pose some hazard or threat to the health of native species (e.g., it magnifies toxin levels; is poisonous; is a pathogen, parasite, or a vector of either)?

Yes, and it has impacted threatened/endangered species, resulted in the reduction or extinction of one or more native populations, affects multiple species, or is a reportable disease	6
Yes, but negative consequences have been small (e.g., limited number of infected individuals, limited pathogen transmissibility, mild effects on populations and ecosystems)	1 √
Not significantly	0
Unknown	U

- *Density of phytoplankton (except cyanobacteria) was always higher outside S. aloides than between rosettes, both in surveys, in situ field experiments and laboratory microcosm experiments (Mulderij et al. 2006). Surveys showed cell density between rosettes at about 25% compared to outside rosettes. In site experiments showed chlorophyll concentrate at about 60% between rosettes at about 25% compared to outside rosettes. This study concluded that allelopathic substances are excreted by S. aloides. The negative effect may be amplified in natural environments due to other stresses such as shading and grazing.*
- *Mulderij et al. (2005) showed the effect on several phytoplankton species: two cyanobacterial strains (toxic and non-toxic (Microcystis aeruginosa), one green alga (Scenedesmus obliquus) and one eustigmatophyte (Nannochloropsis limnetica). The overall effect (8-51%) was measured by the extendsion in doubling time of initial biovolume.*

E2) Does it out-compete native species for available resources (e.g., habitat, food, nutrients, light)?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species or caused critical reduction, extinction, behavioral changes including modified spawning behavior) on one or more native populations	6
Yes, and it has caused some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population	1 √
Not significantly	0
Unknown	U

- *This species has formed dense colonies of large number (22,000 plants in seven colonies) in Trent River, Ontario (Campbell 2009).*
- *This species has been described by government agencies as likely to crowd out native vegetation (OMNR 2009), though no primary literature exists to support this in introduced habitats. It does form "dense, almost monospecific stands" in native habitat (Strzałek and Koperski 2009).*

E3) Does it alter predator-prey relationships?

Yes, and it has resulted in significant adverse effects (e.g., impacted threatened/endangered species, caused significant reduction or extinction of one or more native populations, creation of a dead end or any other significant alteration in the food web)	6
Yes, and it has resulted in some noticeable stress to (e.g., decrease in growth, survival, fecundity) or decline of at least one native population AND/OR Yes, and it has resulted in some alteration of the food web structure or processes, the effects of which have not been widespread or severe	1
Not significantly	0 √
Unknown	U

E4) Has it affected any native populations genetically (e.g., through hybridization, selective pressure, introgression)?

Yes, and it has caused a loss or alteration of genes that may be irreversible or has led to the decline of one or more native species (or added pressure to threatened/endangered species)	6
Yes, some genetic effects have been observed, but consequences have been limited to the individual level	1
Not significantly	0 √
Unknown	U

E5) Does it negatively affect water quality (e.g., increased turbidity or clarity, altered nutrient, oxygen, or other chemical levels/cycles)?

Yes, and it has had a widespread, long-term, or severe negative effect on water quality AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected water quality to some extent, but the alterations and resulting adverse effects have been limited or inconsistent (as compared with above statement)	1 √

Not significantly	0
Unknown	U

- *Has the potential to alter surrounding water chemistry, which may harm phytoplankton and other aquatic organisms (OMNR 2009). The exact mechanism has not been elucidated, but the likely cause is allelopathy (Mulderij et al. 2006). Other potential explanations follow.*
- *Density of phytoplankton (except cyanobacteria) was always higher outside S. aloides than between rosettes, both in surveys, in situ field experiments and laboratory microcosm experiments (Mulderij et al. 2006). Surveys showed cell density between rosettes at about 25% compared to outside rosettes. In site experiments showed chlorophyll concentrate at about 60% between rosettes at about 25% compared to outside rosettes. This study concluded that allelopathic substances are excreted by S. aloides. The negative effect may be amplified in natural environments due to other stresses such as shading and grazing.*
- *Mulderij et al. (2005) showed the effect on several phytoplankton species: two cyanobacterial strains (toxic and non-toxic (*Microcystis aeruginosa*), one green alga (*Scenedesmus obliquus*) and one eustigmatophyte (*Nannochloropsis limnetica*). The overall effect (8-51%) was measured by the extendsion in doubling time of initial biovolume.*
- *S. aloides exerted a negative influence upon contiguous populations of phytoplankton in Sweden and in Poland. A considerable decline in planktonic chlorophyll was accompanied by decreases in electrolytic conductivity, carbonate alkalinity and contents of calcium, potassium and sodium. Low concentrations of molybdate-reactive phosphorus in the water of the Stratiotes community was credited to co-precipitation with calcium carbonate on the leaf surfaces of the submerged plants. Thus, rather than allelopathy, competition for essential nutrients together with changes in the ionic composition of the water seemed to be a more likely explanation for the decline in phytoplankton (Brammer 1979).*
- *Inhibition may also occur through inhibition of the enzyme alkaline phosphatase, which is associated with the growth of phytoplankton (Addisie and Medellin 2012).*

E6) Does it alter physical components of the ecosystem in some way (e.g., facilitated erosion/siltation, altered hydrology, altered macrophyte/phytoplankton communities, physical or chemical changes to substrate)?

Yes, and it has had a widespread, long term, or severe negative effect on the physical ecosystem AND/OR Yes, and it has resulted in significant negative consequences for at least one native species	6
Yes, it has affected the physical ecosystem to some extent, but the alterations and resulting adverse effects have been mild	1
Not significantly	0 √
Unknown	U

Environmental Impact Total	**3**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	**<u>Moderate</u>**

0	0-1	Low
1	0	
0	≥2	Unknown
1	≥1	

POTENTIAL SOCIO-ECONOMIC IMPACT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular impact. An "Unknown" response is appropriate if the potential for a particular impact might be inferred from a significant environmental impact but has not been explicitly reported or if there is an unresolved debate about a particular impact.

S1) Does the species pose some hazard or threat to human health (e.g., it magnifies toxin levels, is poisonous, a virus, bacteria, parasite, or a vector of one)?

Yes, significant effects on human health have already been observed	6
Yes, but negative consequences have not been widespread, long lasting, or severe	1 √
Not significantly	0
Unknown	U

- *Sharp leaves of this species can cut skin (Campbell 2009).*

S2) Does it cause damage to infrastructure (e.g., water intakes, pipes, or any other industrial or recreational infrastructure)?

Yes, it is known to cause significant damage	6
Yes, but the costs have been small and are largely reparable or preventable	1
Not significantly	0 √
Unknown	U

S3) Does it negatively affect water quality (i.e. in terms of being less suitable for human use)?

Yes, it has significantly affected water quality, and is costly or difficult to reverse	6
Yes, but the effects are negligible and/or easily reversed	1
Not significantly	0 √
Unknown	U

S4) Does it negatively affect any markets or economic sectors (e.g., commercial fisheries, aquaculture, agriculture)?

Yes, it has caused significant damage to one or more markets or economic sectors	6
Some damage to markets or sectors has been observed, but negative consequences have been small	1

Not significantly	0 √
Unknown	U

S5) Does it inhibit recreational activities and/or associated tourism (e.g., through frequent water closures, equipment damage, decline of recreational species)?

Yes, it has caused widespread, frequent, or otherwise expensive inhibition of recreation and tourism	6
Yes, but negative consequences have been small	1 √
Not significantly	0
Unknown	U

- *Dense floating mats of water soldier can hinder recreational activities, such as boating, angling and swimming.*

S6) Does it diminish the perceived aesthetic or natural value of the areas it inhabits?

Yes, the species has received significant attention from the media/public, significantly diminished the natural or cultural character of the area, or significantly reduced the area's value for future generations	6
Yes, but negative consequences have been small	1
Not significantly	0
Unknown	U √

- *This would likely result from a massive infestation, but has not been quantified.*

Socio-Economic Impact Total	**2**
Total Unknowns (U)	**1**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	**<u>Moderate</u>**
0	0-1	Low
1	0	
0	≥2	Unknown
1	≥1	

POTENTIAL BENEFICIAL EFFECT

NOTE: In this section, a "Not significantly" response should be selected if there have been no reports of a particular effect. An "Unknown" response is appropriate if the potential for a particular effect might be inferred but has not been explicitly reported or if there is an unresolved debate about a particular effect.

B1) Does it act as a biological control agent for aquatic weeds or other harmful nonindigenous organisms?

Yes, it has succeeded significantly as a control agent	6
Yes, it has had some success as a control agent, but may be inconsistent or lack a desired level of effectiveness	1
Not significantly	0 √
Unknown	U

B2) Is it commercially valuable (e.g., for fisheries, aquaculture, agriculture, bait, ornamental trade)?

Yes, it is economically important to at least one of these industries	6
Yes, but its economic contribution is small	1
Not significantly	0 √
Unknown	U

B3) Is it recreationally valuable (e.g., for sport or leisurely fishing, as a pet, or for any other personal activity)?

Yes, it is commonly employed recreationally and has some perceived value for local communities and/or tourism	6
It is sometimes employed recreationally, but adds little value to local communities or tourism	1
Not significantly	0 √
Unknown	U

B4) Does the species have some medicinal or research value (i.e. outside of research geared towards its control)?

Yes, it has significant medicinal or research value	6
It has some medicinal or research value, but is not of high priority OR It is potentially important to medicine or research and is currently being or scheduled to be studied	1 √
Not significantly	0
Unknown	U

- *The herb has had a high reputation for treating wounds, especially when these are made by an iron implement. It is applied externally. The plant is also said to be of use in the treatment of St. Anthony's Fire and also of bruised kidneys (*Grieve 1984*).*

B5) Does the species remove toxins or pollutants from the water or otherwise increase water quality?

Yes, it reduces water treatment costs or has a significant positive impact for the health of humans and/or native species	6
Yes, but positive impact for humans or native species is considered negligible	1
Not significantly	0 √
Unknown	U

B6) Does the species have a positive ecological impact outside of biological control (e.g., increases the growth or reproduction rates of other species, fills an important gap in the food web, supports the survival of a species that is threatened, endangered species, or commercially valuable)?

Yes, it significantly contributes to the ecosystem in one or more of these ways	6
Yes, it provides some positive contribution to the ecosystem, but is not vital	1
Not significantly	0 √
Unknown	U

- *It protects larvae of an endangered dragonfly in native habitat (Rantala et al. 2004), but this is not a concern in the Great Lakes.*

Beneficial Effect Total	**1**
Total Unknowns (U)	**0**

Scoring		
Score	# U	Impact
>5	Any	High
2-5	Any	Moderate
0	0-1	**Low**
1	0	
0	≥2	Unknown
1	≥1	

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