Modeling Bioenergetic Habitat Suitability for Invasive Bigheaded Carp in Lake Michigan

Peter Alsip[1], Hongyan Zhang[1,2]; Mark Rowe,[1,2] , Edward Rutherford[3], Doran Mason[3], Catherine Riseng[1], Zhenming Su[4]

[1] University of Michigan, School of Environment and Sustainability, Ann Arbor, Michigan
[2] University of Michigan, Cooperative Institute for Great Lakes Research, Ann Arbor, Michigan
[3] National Oceanic and Atmospheric Administration, Great Lakes Environmental Research Laboratory, Ann Arbor, Michigan
[4] Michigan Department of Natural Resources, Institute for Fisheries Research, University of Michigan, Ann Arbor, Michigan

Introduction

Bighead and **Silver Carp** (collectively **bigheaded carp 'BHC'**):

- Highly invasive planktivorous fishes that have become prolific in the Mississippi River Basin
- Threaten to invade Lake Michigan and wreak havoc on the Great Lakes food web and $7 billion recreational fishery

Does Lake Michigan provide suitable habitat?

- The lake wide reduction in plankton following the *Dreissena* invasion has transformed most of Lake Michigan (Fig. 2) into a 'plankton desert'[1].
- Prior models[1,2] indicate habitat is limited to a few nearshore areas but these models did not consider:
  - The fishes' flexible diet, which can include detritus
  - The availability of subsurface prey, such as the deep chlorophyll layer that forms during summer stratification

We built off previous research by:

- **Incorporating detritus** into BHC model diets to investigate the impact of a flexible diet on habitat suitability
- **Evaluating the entire volume of Lake Michigan** habitat using a Growth Rate Potential approach (Fig. 3) and simulated water quality data from a 3D biophysical model (Fig. 2).

Figure 1. Bighead Carp *Hypophthalmichthys nobilis* (top) and Silver Carp (*Hypophthalmichthys molitrix* (bottom).

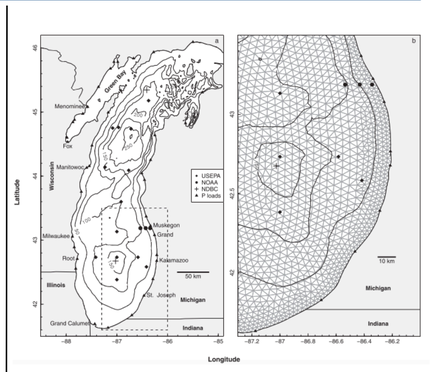

Figure 2. FVCOM-GEM's spatial domain (Lake Michigan, left) and a portion of its unstructured grid (right). The grid contains 5795 nodes each with 20 vertical terrain-following sigma layers[3].

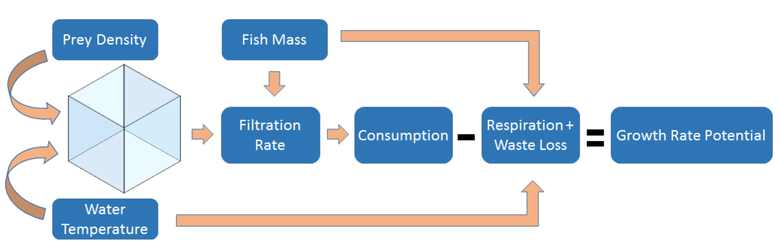

Figure 3. Conceptual diagram of growth rate potential (GRP) model. A filtration rate equation is applied to prey density (J/L) and temperature (C°) inputs to estimate consumption rate within each 3D cell in the FVCOM grid. Energetic costs (Respiration and Waste Loss) are subtracted from consumption to determine fish growth rate potential.

Methods and Materials

Data source: The Lake Michigan Finite Volume Community Ocean Model-General Ecosystem Module (FVCOM-GEM) is a 3-dimensional biophysical model with an unstructured grid[3]. FVCOM-GEM provided the prey (zooplankton, phytoplankton, detritus) and temperature inputs for our growth rate potential (**GRP**) model as well as a spatial grid to visualize habitat suitability (Fig. 2).

Model Bias: FVCOM-GEM's accuracy was not assessed for nodes within Green Bay, so we compared reported values of prey biomass to simulated values to highlight a potential bias source in our GRP model.

Growth Rate Potential Model: We developed a coupled foraging-bioenergetics model that integrated temperature and prey data within each 3D cell of the FVCOM grid to evaluate habitat quality as indexed by fish growth (g/g/day) throughout Lake Michigan (Fig. 3). **Suitable habitat was defined as any cell with GRP >= 0 g/g/day.**

Feeding scenarios:

- Ran 6 scenarios (Fig. 4) to evaluate the effects of subsurface prey and diet flexibility on the extent (km^3) of suitable habitat.

Seasonal Analysis:

- Estimated variation and extent (km3) of suitable growth habitat from April thru November.

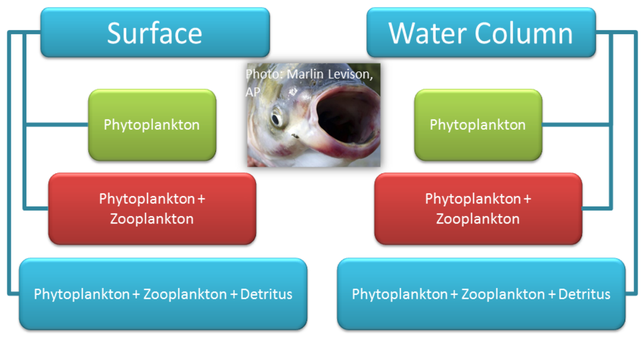

Figure 4. Feeding scenarios were characterized by two factors: 1) Water volume available for carp to feed at/throughout (Surface or the whole water column); 2) Prey available to carp.

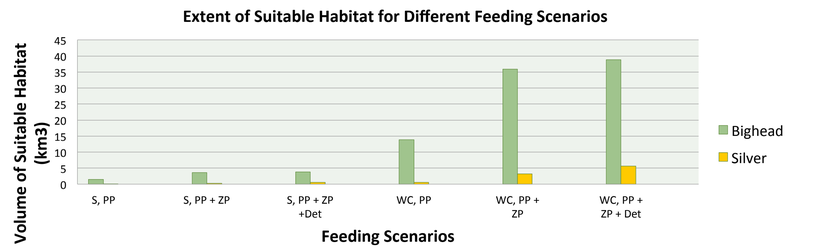

Figure 5. Extent of suitable habitat for Bighead and Silver carp under all feeding scenarios. S = Surface, WC = Water column, PP = phytoplankton, ZP = Zooplankton, Det = Detritus.

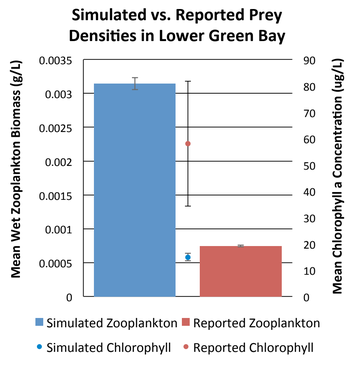

Figure 6. Simulated prey biomass in lower Green Bay from FVCOM-GEM compared to reported values[4,5].

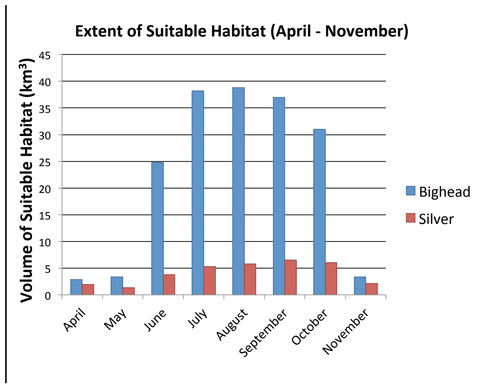

Figure 7. Seasonal fluctuation in modeled suitable habitat for BHC growth in Lake Michigan.

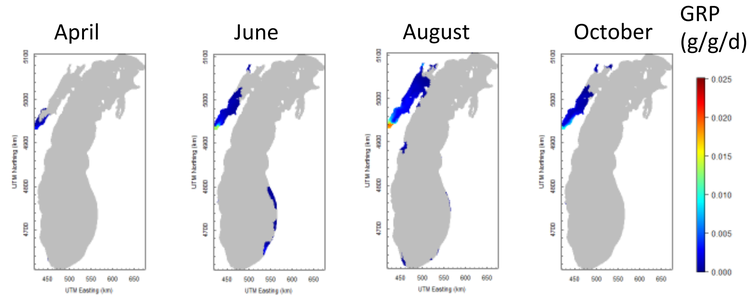

Figure 8. Seasonal habitat dynamics for Bighead Carp.

Results

- Simulation of BHC feeding on all prey types thru the water column produced the greatest volume of suitable habitat (Fig. 5).
- FVCOM-GEM overestimated zooplankton biomass and underestimated chl *a* concentrations in Lower Green Bay (Fig. 6).
- Suitable BHC habitat peaked in late summer and early fall (Figs. 7, 8).
- Suitable habitat in Lake Michigan is more limited for Silver Carp than for Bighead Carp (Fig. 7).
- The extent and location of suitable habitat varies seasonally, but it is concentrated in a few nearshore areas (Fig. 8).

Conclusions and Discussions

- A broad diet and availability of subsurface prey increases the extent of suitable BHC habitat, which was concentrated in Green Bay and a few river mouths in SE Lake Michigan.
- However, habitat in most of Lake Michigan cannot support BHC growth — confirming previous studies[1,2].
- Modeling suitable BHC habitat can inform management by identifying areas at risk of BHC establishment and helping to prioritize surveillance efforts.
- Further calibration of simulated water quality data in Green Bay is needed to reduce uncertainty in GRP estimates.

References

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Support

Sea Grant Michigan

GLANSIS Great Lakes Aquatic Nonindigenous Species Information System