MID-ATLANTIC
FISHERY MANAGEMENT COUNCIL

Ecosystem Approach to Fisheries Management Guidance Document

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Acronyms and Abbreviations

ASMFC	Atlantic States Marine Fisheries Commission
B	Biomass
B_{ERP}	Biomass Ecological Reference Point
B_{MSY}	Biomass at Maximum Sustainable Yield
B_0	Virgin Biomass
Council	Mid-Atlantic Fishery Management Council
EAFM	Ecosystem Approach to Fisheries Management
EBFM	Ecosystem Based Fishery Management
EC	Ecosystem Component
EEZ	Exclusive Economic Zone
EFH	Essential Fish Habitat
EFP	Exempted Fishing Permit
ESR	Ecosystem Status Reports
F	Fishing Mortality Rate
F_{ERP}	Fishing Mortality Ecological Reference Point
FMP	Fishery Management Plan
F_{MSY}	Fishing Mortality Rate at Maximum Sustainable Yield
HAPC	Habitat Areas of Particular Concern
ICES	International Council for the Exploration of the Sea
IEA	Integrated Ecosystem Assessment
ITQ	Individual Transferable Quota
M	Natural Mortality Rate
MAFMC	Mid-Atlantic Fishery Management Council
MARMAP	Marine Resources Monitoring, Assessment and Prediction
MSA	Magnuson-Stevens Fishery Conservation and Management Act
MSE	Management Strategy Evaluation
MSY	Maximum Sustainable Yield
NEFSC	Northeast Fisheries Science Center
NES LME	Northeast U.S. Continental Shelf Large Marine Ecosystem
NESDIS	National Environmental Satellite, Data, and Information Service
NEVA	Northeast Fisheries Climate Vulnerability Assessment
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NOC	National Ocean Council
OFL	Overfishing Limit
OY	Optimum Yield
Q	Survey Catchability
RPB	Regional Planning Body
SAV	Submerged Aquatic Vegetation
SBRM	Standardized Bycatch Reporting Methodology
SSC	Scientific and Statistical Committee
WGNARS	Working Group on the Northwest Atlantic Regional Sea

1. Introduction

1.1 Mid-Atlantic Fishery Management Council

The Mid-Atlantic Fishery Management Council (also referred to as the Council, Mid-Atlantic Council, or MAFMC) is responsible for the conservation and management of fish stocks within the federal 200-mile limit of the Mid-Atlantic region (North Carolina through New York).

The Council was established in 1976 by the Fishery Conservation and Management Act (later renamed the Magnuson-Stevens Fishery Conservation and Management Act, or MSA). The law created a 200-mile Exclusive Economic Zone (EEZ), eliminated foreign fishing effort within the EEZ, and charged eight regional councils with management of fishery resources in the newly expanded federal waters. The Council develops fishery management recommendations which must be approved by the secretary of commerce before they become final. All of the Council's fishery management recommendations must be consistent with the ten national standards as defined by the MSA.

The Council manages more than 64 species with seven fishery management plans (FMPs). Fourteen species are directly managed with specific FMPs. These include summer flounder, scup, black sea bass, Atlantic bluefish, Atlantic mackerel, *Illex* and longfin squids, butterfish, Atlantic surfclams, ocean quahogs, golden and blueline tilefish, spiny dogfish (joint with the New England Council), and monkfish (joint with the New England Council). The Council coordinates the management of summer flounder, scup, black sea bass, bluefish, and spiny dogfish jointly with the Atlantic States Marine Fisheries Commission (ASMFC). In addition, the Council manages more than 50 forage species as "ecosystem components" in all seven FMPs. The Council sets possession and landing limits to prevent the expansion of directed fisheries on these forage species in the Mid-Atlantic.

The Council is composed of 25 members, including citizens from each of the seven mid-Atlantic states as well as representatives of the U.S. Fish and Wildlife Service, U.S. Coast Guard, State Department, and the Atlantic States Marine Fisheries Commission.

1.2 Purpose of this Document

The purpose of the *Ecosystem Approach to Fisheries Management Guidance Document* is to facilitate the transition from single-species management toward an approach that manages fisheries within a broader ecosystem context.

This document articulates the Council's policy with respect to the incorporation of ecosystem considerations into its current management programs through a series of policy statements and other recommendations. Based on this guidance, initial implementation of Council management actions with respect to ecosystem considerations will occur in a consistent, coordinated fashion within the context of the current FMP structure.

1.3 Development of the EAFM Guidance Document

The Council has been considering mechanisms to introduce ecosystem considerations into the fishery management process since the late 1990s (MAFMC 2006). In the fall of 2011, the Council hosted the fourth National Scientific and Statistical Committee Workshop, which was convened to provide an opportunity for the eight regional fishery management councils' Scientific and Statistical Committees (SSCs) to discuss incorporation of ecosystem considerations in federal fisheries management (Seagraves and Collins 2012). After a review of the various approaches to incorporating ecosystem considerations into fishery management around the U.S., the Council agreed to move forward with development of a transitional approach to introduce ecosystem considerations into Council management actions in a step-wise, evolutionary fashion – herein referred to as an *ecosystem approach to fisheries management* or EAFM.

The Council also embarked on a Visioning Project in 2011 to chart a course for the future of marine fisheries management in the Mid-Atlantic based on extensive stakeholder input. This effort culminated in the development of the Council's 2014-2018 Strategic Plan (http://www.mafmc.org/strategic-plan), which established an overarching goal of maintaining sustainable fisheries, ecosystems, and habitats in the Mid-Atlantic through the development of management approaches that minimize adverse ecosystem impacts. This EAFM Guidance Document addresses objective 15 of the strategic plan - *Advance ecosystem approaches to fisheries management in the Mid-Atlantic (i.e., through development of EAFM Guidance Document).*

Based on Council and SSC discussions and stakeholder input from the Council's Visioning Project, the Council concluded that the EAFM document should focus on the following major ecosystem-related issues[1]:

1. Forage/low trophic level species considerations;
2. Incorporation of ecosystem-level habitat conservation and management objectives in the current management process;
3. Effects of systematic changes in oceanographic conditions on abundance and distribution of fish stocks and ramifications for existing management approaches/programs; and
4. Interactions (species, fleet, habitat, and climate) and their effects on sustainable harvest policy and achievement of Optimal Yield (OY).

The Council organized a series of four workshops between 2013 and 2015 which brought together scientists, managers, and stakeholders to discuss each of the four topics and associated best management practices. After completion of the workshops, the Council developed white papers which provide detailed information and in-depth discussion on each of these topics[2]. This guidance document builds upon that foundation for establishing an EAFM in the Mid-Atlantic Region.

This document was developed as a "how-to" guide to facilitate the Council's transition to EAFM. Sections 2 through 5 are structured around each of the four major ecosystem-related issues and discuss policy guidelines and recommendations which address incorporation of ecosystem considerations into Council assessment and management programs.

It is important to note that the Council policies articulated in this document are based on current available scientific data and analyses. As new information and analytical tools become available, the Council fully anticipates that future policy with respect to incorporation of ecosystem considerations into assessment and management will be revised based on the adaptive framework established in this guidance document.

1.4 EAFM Definition & Goal

The Council's definition of EAFM is "**An ecosystem approach to fishery management recognizes the biological, economic, social, and physical interactions among the components of ecosystems and attempts to manage fisheries to achieve optimum yield taking those interactions into account**." In contrast with Ecosystem Based Fisheries Management (EBFM), which attempts to manage the ecosystem as an entity to account for

[1] Social and economic considerations were integrated throughout the analyses of the four topic areas.

[2] Workshop materials, presentations, and white papers are all available at http://www.mafmc.org/eafm/

species/interactions of interest, EAFM attempts to manage species while considering the broader interactions within the ecosystem.

In addition, the Council developed the following EAFM goal:

> **To manage for ecologically sustainable[3] utilization of living marine resources while maintaining ecosystem productivity, structure, and function.**

This approach addresses several key elements necessary for the successful implementation of an EAFM. The first is the need to carefully develop a transition strategy to move from the current single-species focused management system to more of a multi-species/ecosystem-based one. This transitional approach will allow the Council to meet its current single-species based MSA requirements with respect to the prevention of overfishing and attainment of OY while moving towards a definition of OY which truly accounts for interactions at multiple dimensions of the environment/ecosystem, of which humans are inextricably a major component. Importantly, the approach allows for the growth and development of EAFM policy at a rate commensurate with the availability of the science necessary to support it. The Council recognizes that stakeholder involvement is imperative to success and that EAFM will require engagement of a broader range of stakeholder interests compared to traditional fisheries management.

1.5 Geographic Range of EAFM

A description of the Northeast U.S. Continental Shelf Large Marine Ecosystem (NES LME) provided by the Northeast Fisheries Science Center (NEFSC) is given in Appendix I[4] and encompasses Cape Hatteras, North Carolina in the south to the Gulf of Maine in the north. While the jurisdictional boundaries of the Mid-Atlantic Council extend from New York to the North Carolina-Virginia border, the management units specified in Council fishery management plans extend throughout the range of the species under management (the case for all managed species). For example, the management unit for the Atlantic Bluefish FMP extends from the East Coast of Florida to the U.S.-Canadian border. Thus, bluefish transcend the boundaries of ecosystems north and south of Cape Hatteras, the southern boundary of the NES LME described in Appendix I. From an operational standpoint, guidance provided in this document shall apply to the species under consideration throughout its management unit (which, in many cases, extends well north and south of the boundaries of the NES LME).

[3] Ecologically sustainable utilization is defined as utilization that accommodates the needs of present and future generations, while maintaining the integrity, health, and diversity of the marine ecosystem.

[4] Appendix I to this document can be viewed at: http://www.mafmc.org/s/EAFM-Appendix-1.pdf.

2. Forage Species

2.1 Background

Forage species are generally small, mostly planktivorous fishes and invertebrates and are some of the most abundant fishes in the Mid-Atlantic region (see Table 2 in the Forage White Paper[5]). Collectively, forage species provide a key ecological service of energy transfer given their importance in the marine food web. In addition, forage species tend to be highly productive relative to larger predatory fish, marine mammals, and birds. Forage species have diverse life histories and encompass a wide range of coastal, offshore and deep-water habitats.

Within the Council's jurisdiction, there are two broad forage species categories: 1) the targeted, managed species and 2) unfished and unmanaged[6] forage species. The first category includes *Illex* and longfin squids, butterfish, and Atlantic mackerel which are targeted fisheries that have been managed by the Council since 1983.[7] The second category includes numerous small and abundant fish such as bay anchovy and sand lance that are not generally targeted by fisheries. None of the unmanaged forage species have been assessed, and there are no biomass or abundance estimates. Some are species of concern since they may be at low population levels and/or occur as bycatch in fisheries for managed species in the Mid-Atlantic and New England (e.g., river herrings). With climate change, some of the more southern species now supporting small fisheries in the South Atlantic and Gulf of Mexico (e.g., thread herring, Spanish sardine) might become abundant enough to warrant fishing in Mid-Atlantic waters. Sand lance, while not fished much historically in the western Atlantic, has had large catches in the Eastern Atlantic and might be targeted.

The Council and its constituent stakeholder groups have expressed strong interest in the development of a policy and approach for the management of forage fisheries (MAFMC 2012). The role of forage species in Mid-Atlantic ecosystems and potential considerations for their management were evaluated in-depth in the Council's Forage Fish White Paper.

Essington et al. (2015a) present a strong argument that special safeguards protecting heavily exploited forage stocks should be in place due to the important role they play in the transfer of energy in marine food webs. They note that forage fish collapses share a common and unique set of circumstances: high fishing pressure for several years before collapse, a sharp drop in natural population productivity, and a lagged response to reduced fishing pressure. The authors demonstrate that the magnitude and frequency of forage species collapses are greater than expected from natural productivity characteristics (which can likely be attributed to fishing). The authors conclude that a risk-management approach that reduces fishing pressure when populations become scarce should be in place to protect forage stocks and their predators.

Szuwalski and Hilborn (2015) argue that the productivity of forage fish stocks is driven primarily by environmental factors through the regulation of recruitment processes and that fishing plays little, if any, role in the collapse of forage stocks. The authors conclude that management should respond to collapses in recruitment by preventing fishing mortality from increasing as biomass declines, rather than waiting for biomass

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[5] See http://www.mafmc.org/s/MAFMC-Forage-White-Paper_Nov2014.pdf

[6] Note: the term "unmanaged" refers to those forage species not managed by the Mid-Atlantic Council as a stock in a fishery management plan or a stock in need of conservation and management.

[7] Note: this document focuses on managed forage species within the management jurisdiction and authority of the Mid-Atlantic Council. There are other targeted forage species managed by other state, inter-state Commissions and federal Councils that are not explicitly addressed here.

to decline and then reacting. In rebuttal, Essington et al. (2015b) emphasized that fishing pressure tends to amplify natural troughs in production of forage stocks which can lead to further depletion and have negative consequences for obligate predators within the ecosystem. They argue that fishing strategies need to avoid, to the extent possible, depleting forage fish stocks below critical ecological thresholds. Both papers agree that management should respond to declines in recruitment as an early indicator of decreased productivity. Anticipating recruitment failures through monitoring of these stocks is critical and remains one of the primary challenges in the assessment and management of forage fish stocks.

2.2 Council Forage Policy

A consensus is emerging that forage and/or low trophic level species should be managed more conservatively than the MSY-based conservation and management standard described within the MSA because of the important role they play within the ecosystem. To that end, the Council adopted the following policy:

> **It shall be the policy of the Council to support the maintenance of an adequate forage base in the Mid-Atlantic to ensure ecosystem productivity, structure and function and to support sustainable fishing communities.**

2.3 Science and Management Strategies for Forage Species

The following sections describe science and management strategies the Council is considering or has already initiated to address the unique management needs of forage species.

2.3.1 Modifications to Biological Reference Points

For forage species directly managed by the Council, special management objectives could be accomplished through modification to the Council's risk policy and ABC control rule framework in several ways. First, the Council could adopt biological reference points (overfishing limits or OFLs) for forage stocks that are more conservative than the required MSA standard of F_{MSY}. We would expect the stock in question to be maintained at biomass levels that exceed B_{MSY}. Candidate reference points in this regard include fishing mortality rates that do not exceed the natural mortality rate (i.e., $F<M$) or are specified as some fraction of the natural mortality rate, among others (Table 1).

Table 1: Potential precautionary biological reference points for managed forage fish fisheries. Empirical mortality- and biomass-based reference points. F is the fishing mortality rate; F_{MSY} is the F level to achieve maximum sustainable yield; M is the instantaneous natural mortality; F_{ERP} is an ecological reference point for F; B_{ERP} is an ecological reference point for biomass; and B_0 is virgin biomass.

Mortality-based reference points	**Source**
$F = M$	Beverton 1990
$F = 0.87\ M$	Zhou et al. 2012
$F = 0.67\ M$	Patterson 1992
$F_{ERP} = (0.2, 0.5 \text{ or } 0.75)\ F_{MSY}$	Pikitch et al. 2012
Biomass-based reference points	**Source**
$B_{ERP} = 0.75\ B_0$	FAO 2003, Smith et al. 2011
$B_{ERP} = (0.8, 0.4, \text{or } 0.3)\ B_0$	Pikitch et al. 2012

Reference points based on this convention should be considered as a starting point for evaluation of potential biological reference points for managed forage species. For example, the Council adopted an OFL for Atlantic butterfish based on a fishing mortality rate of F=0.67 M. This option has the potential to perform as a stand-alone measure when implemented within the existing Council risk policy framework, depending on the life history of the species of interest and the Council's specific objectives relative to the forage species in question.

The potential reference points for forage species described in Table 1 represented the best science available at the time this document was developed. The issue of specification of biological reference points for forage species is a source of ongoing scientific debate, and the Council anticipates that future policies and management decisions will continue to be refined as new information becomes available.

2.3.2 Modifications to Existing Council Risk Policy

Another option would be to modify the shape of the ABC control rule for forage species through modification of the Council's risk policy. The current default control rule (depicted as the solid black line) and an ***example*** forage control rule (red line) are depicted in Figure 1.

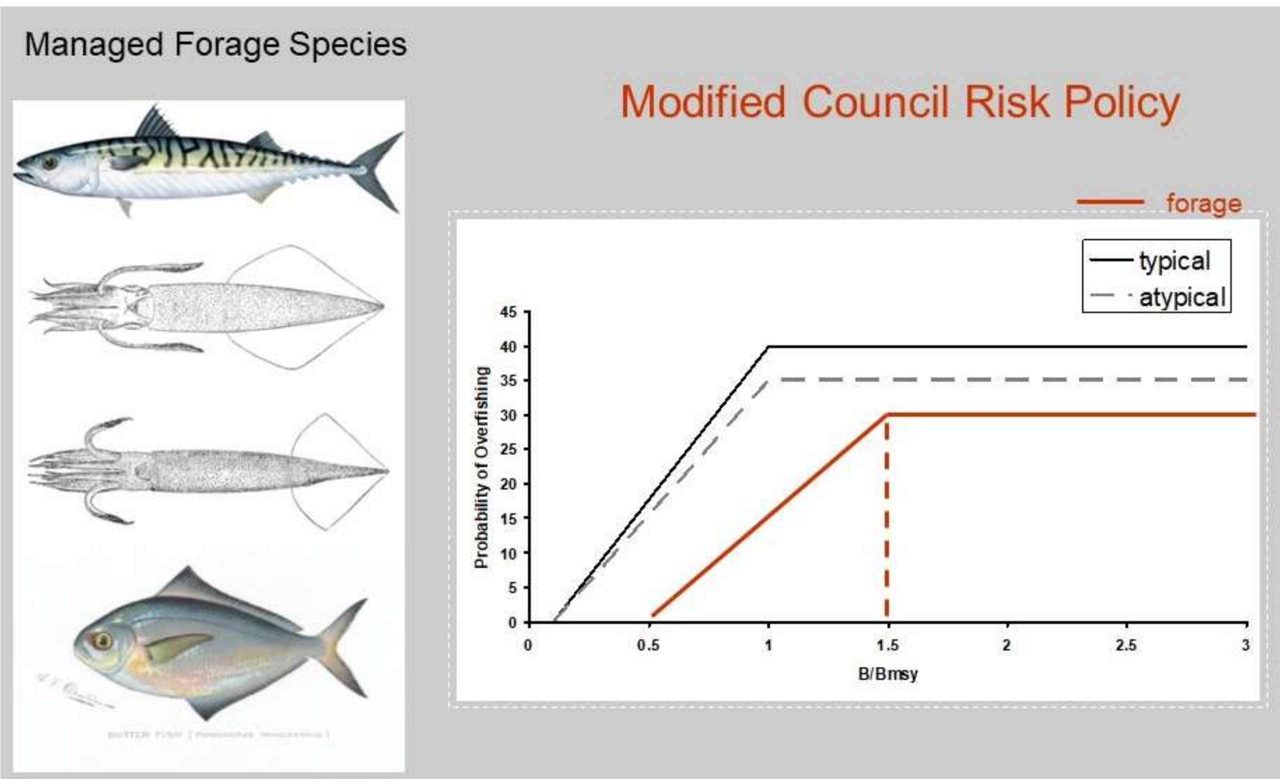

Figure 1: Example modification (red line) to the Council's ABC framework and risk policy for forage species.

According to the existing control rule (black line above), the Council's maximum tolerance for risk of overfishing is specified at 40% (i.e., when the stock is at or above B_{MSY}). Below B_{MSY} the Council's tolerance for risk of overfishing declines linearly with stock size to a level of 10% of B_{MSY}, at which point fishing mortality would be reduced to zero to prevent any further stock declines. This functional control rule is designed to automatically trigger required reductions in fishing mortality as stocks decline below B_{MSY}, which, in turn, should result in increases in stock biomass and cause stock size to increase.

Modifications to the existing risk policy to accommodate ecosystem-level concerns for forage species could be accomplished by reducing the maximum tolerance for risk of overfishing. For example, forage species currently managed by the Council (*Illex* and longfin squid, butterfish, and Atlantic mackerel) could be managed by maintaining the current OFL fishing mortality rate (F_{MSY} based or proxy) and reducing the maximum probability of overfishing to 35% (the default value chosen for atypical species) or some other level below the current maximum of 40%. In addition, as depicted in the example red line in Figure 1, the Council could specify a control rule that reduces fishing mortality more aggressively as forage stock biomass declines to address the concern that fishing tends to exacerbate environmentally-driven declines in forage stocks. It is important to note that the potential modification to the risk policy depicted in Figure 1 (red line) is presented as an *example* only; the final policy adopted by the Council for any given species will depend on the outcome of trade-off analyses described in the section below.

2.3.3 Establishing Forage Species Management Policy - Evaluating Trade-Offs

As noted above, managing forage species to achieve ecosystem-level objectives can be accomplished functionally through modifications to biological reference points and/or the Council's risk policy. However, these approaches only address ways to maintain (at least theoretically) forage stocks at higher biomass levels to support ecosystem-level objectives from a purely biological perspective. Optimal management of forage fish ultimately depends on the trade-off between their *in situ* value versus their harvest market value. Thus, managing these trade-offs requires knowledge of not only the species ecology, but also the uses of and substitutes for these species within the economy. Further, these choices are based not just on ecological preferences and commercial uses, but cultural and social preferences as well.

The role of forage fish in the economy, in terms of both value and substitutability, must be understood. Qualitative and, when feasible, quantitative analyses should be conducted to determine the relative impact of choosing more precautionary biological thresholds for forage fish management. Analysis of economic, social and cultural factors will help identify which forage fish are likely to generate the largest net benefits to society if and more precautionary biological thresholds are adopted.

Development of full bio-socio-economic multispecies models can help estimate optimal forage harvest levels and help generate an understanding of the relative trade-offs between direct and indirect benefits through an understanding of the economic, social and ecological dependence on the forage fish of interest (Charles 1989). Unfortunately, the state of science is such that these models have yet to be practical. While the science to perform these comprehensive models is developed, existing data and the use of population dynamic and social-economic models can be utilized to evaluate these trade-offs in a more structured approach.

2.3.4 Unmanaged Forage Species

In an effort to proactively protect and conserve currently unmanaged forage species, the Council considered a number of options regarding the protection of previously unmanaged forage species. In December 2014, the Council voted to “initiate a regulatory action to prohibit the development of new, or expansion of existing, directed fisheries on unmanaged forage species until adequate scientific information is available to promote ecosystem sustainability." The Council passed this motion with the intent of protecting the important ecological role that forage species play in the Mid-Atlantic.

The Council conducted a scoping process in the fall of 2015 to solicit input from interested members of the public on the types of management measures which could effectively address this motion. After considering recommendations from the Fishery Management Action Team, the Council voted to initiate an omnibus amendment to add unmanaged forage species as Ecosystem Component (EC) species to the relevant FMPs for Council-managed stocks.

In August 2016, the Council approved the Omnibus Unmanaged Forage Amendment, which protects over 50 previously unmanaged forage species in the Mid-Atlantic. Implemented in September 2017, the Unmanaged Forage Omnibus Amendment prohibits the development of new, and expansion of existing, directed commercial fisheries on these species in Mid-Atlantic federal waters until the Council has had an opportunity to assess the available scientific information for these species and consider the potential impacts to existing fisheries, fishing communities, and the marine ecosystem.

The amendment establishes an incidental possession limit for all of the species included in the amendment, with the exception of chub mackerel. For chub mackerel, the Council approved temporary measures, including an annual quota and a possession limit, to be implemented while the Council evaluates potentially adding the species as a stock in the Atlantic Mackerel, Squid, and Butterfish FMP. The amendment also requires use of exempted fishing permits (EFPs) prior to allowing any new fisheries or expansion of existing fisheries for unmanaged forage species and establishes a new policy for Council review of EFP applications. In addition, prior to allowing any new fisheries or expansion of existing fisheries for the forage species included in the amendment, the Council will consider whether the species in question should be managed as a stock in the fishery or if other discretionary management measures should be used. Additional information concerning this Council management action can be found on the Council's website at: http://www.mafmc.org/actions/unmanaged-forage.

3. Habitat

3.1 Background

Habitat is a fundamental component of marine ecosystems and provides the basis for fisheries production. Fish habitats are the places where species live, including the physical, chemical, biological, and geological components of both benthic and pelagic environments (Table 2). A fish's habitat is a combination of physical factors, such as water temperature and bottom type, chemical factors such as oxygen levels and dissolved minerals, and biological and ecological characteristics such as distribution of prey species. Many species of fish have different habitat requirements for each life stage (i.e., egg, larvae, juvenile, adult). Habitat plays an essential role in the reproduction, growth, and sustainability of commercial and recreational target species and is essential to the biodiversity of marine and coastal ecosystems. However, full integration of habitat management and conservation into the fishery management process has been challenging. The following sections describe the Council's approach relative to incorporating habitat into EAFM.

Table 2: Habitat Characteristics Important to Marine Species (modified after NMFS 2010).

Seafloor Structure	Vegetation Emergent epifauna Biogenic reefs (e.g. coral, oyster, sponge) Geomorphology (e.g. rocky outcrops, pinnacles) Physiography (e.g. seamount, submarine canyon)
Sediments	Grain size Organic content Rugosity Stability Slope
Hydrodynamic Processes	Currents/boundaries/fronts Tidal dynamics Wave dynamics Upwelling
Hydrology	Depth/bathymetry Salinity/haloclines Temperature/thermoclines Density/pycnoclines Turbidity Nutrients Dissolved oxygen/oxyclines pH
Anthropogenic Alterations	Pollutants/contaminants Artificial structures (e.g. artificial reef, oil platform) Created habitats (e.g. restored salt marsh, planted seagrass bed) Fishery impacts Marine debris

The MSA requires fishery management councils to identify, describe, map, and conserve Essential Fish Habitat (EFH) for each fish species managed under its jurisdiction. EFH is defined in the MSA as "those waters and substrate necessary to fish [and shellfish] for spawning, breeding, feeding or growth to maturity"[8]. This broad definition has led the Mid-Atlantic and the New England Fishery Management Councils to identify EFH in most, if not all, areas in the Northeast U.S. Shelf Ecosystem, ranging from offshore pelagic areas to nearshore wetlands to streams and rivers. At its most basic level, habitat (in the sense of EFH) is defined separately for each managed species by where that species in any of its life stages has been caught. NMFS produces several resources which compile scientific information on habitat from a variety of sources, including species-specific Essential Fish Habitat Source Documents (http://www.nefsc.noaa.gov/nefsc/habitat/efh/) and the Essential Fish Habitat Mapper (http://www.habitat.noaa.gov/protection/efh/efhmapper/).

The Council first identified EFH for thirteen species in 1998 and updated EFH descriptions for tilefish in 2009. The Council has also identified two Habitat Areas of Particular Concern (HAPCs) to highlight habitat types and areas that are especially valuable to summer flounder and tilefish.

3.2 Ecosystem Related Habitat Policy Statements

Recognizing the essential role habitat plays in reproduction, growth and sustainability of all species in the Mid-Atlantic, the Council adopted the following ecosystem related habitat policy statements:

1. **Strengthen EFH designations and consider essential from a multispecies/ecosystem perspective emphasizing the connectivity between species, life history stages, etc. and inshore and offshore habitats.**
2. **Demonstrate and communicate the value of habitat to managed fisheries and quantitatively link habitat science and conservation to fishery outcomes.**
3. **Encourage NMFS to conduct additional focused sampling in habitats at finer scales than has been historical practice (especially in non-trawl-able habitats). Also, habitat sampling should be expanded temporally, and other sampling methods should be examined.**

3.3 Ecosystem-Level Habitat Guidance

In October 2015 the Council held a workshop focused on ways to effectively consider habitat from an ecosystem-level perspective and integrate habitat information into an EAFM approach[9]. Discussion at the workshop resulted in a number of key points and considerations described below to provide ecosystem-level habitat guidance to the Council.

3.3.1 Demonstrate and communicate the value of habitat to managed fisheries, and transition to landscape/ecosystem-level habitat descriptions and conservation.

Habitats provide ecological benefits to species reproduction, growth, and survival and play a fundamental role in supporting fishery and ecosystem production (NMFS 2015). There is ongoing work to integrate the critical role of habitat in the Northeast Integrated Ecosystem Assessment (IEA)[10]. An IEA is an approach to Ecosystem-Based Management which integrates all components of an ecosystem, including humans, into the decision-making

[8] 16 U.S.C. 1802 (10)

[9] Workshop materials and presentations are available at: http://www.mafmc.org/workshop/2015/eafm-habitat-considerations.

[10] For more information about NOAA's IEA program visit, https://www.integratedecosystemassessment.noaa.gov/.

process so that managers can balance trade-offs and determine what is more likely to achieve their desired goals.

An IEA framework may be helpful for organizing and considering the specific habitat processes. At the ecosystem level, fisheries interactions with both large-scale environmental drivers and human activities are mediated by habitat, impacting outcomes for the ecological systems under management. A possible conceptual model demonstrating these linkages shows how healthy habitat supports biological objectives (e.g., healthy biomass levels, production, and trophic structure) for managed species, which in turn support objectives for human well-being (e.g., seafood production, recreational opportunities, profitability, employment, stability, and culture; Figure 2). Using a framework like this, connections between habitats within and outside Council jurisdiction and Council-managed species can be visualized and eventually quantified. This would complement existing single stock oriented EFH by taking a system-wide perspective.

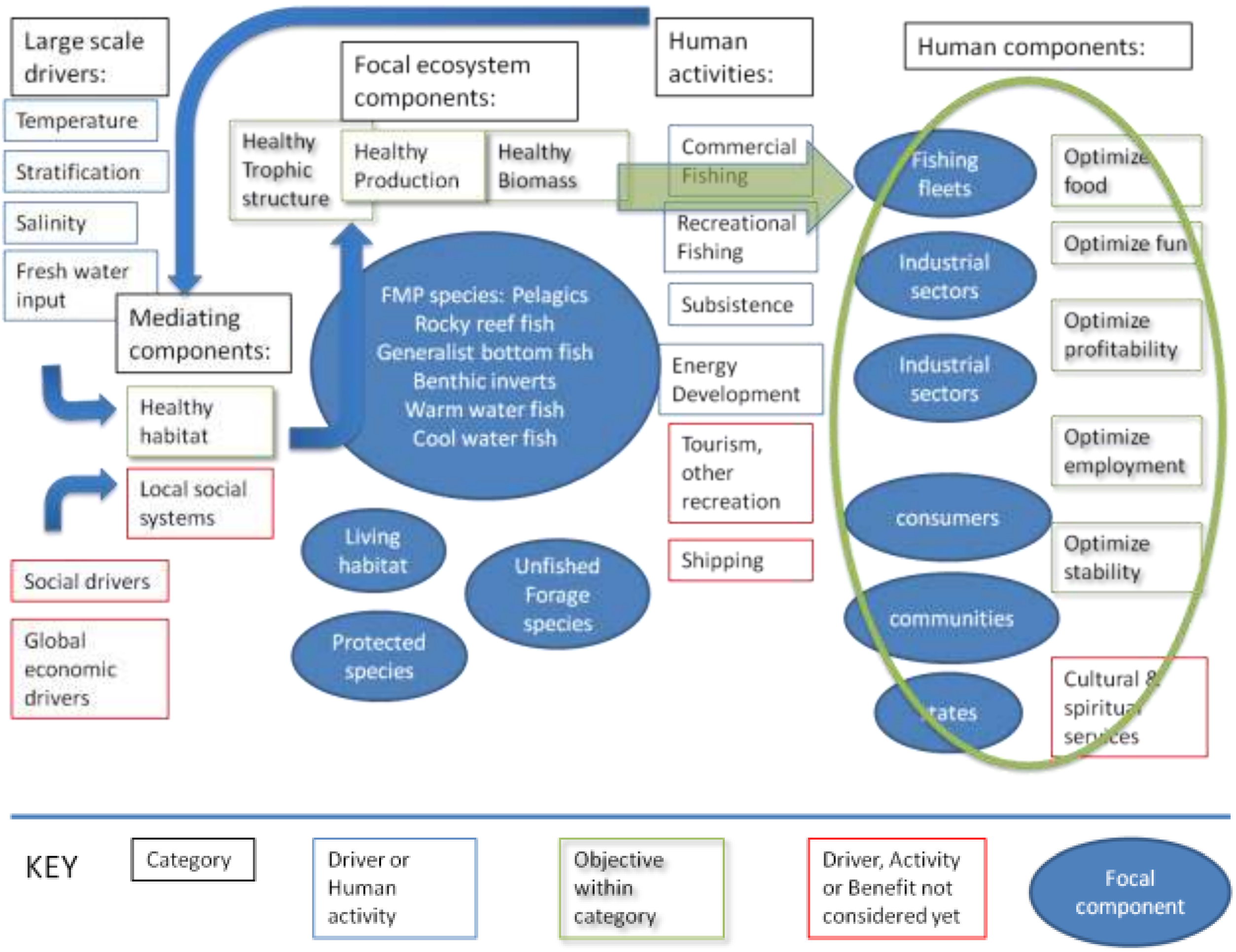

Figure 2: Potential conceptual model for habitat interactions in a Northeast IEA (draft suggested as a starting point for further discussion).

In the Northeast IEA, the key habitat types are Freshwater/Estuarine, Nearshore, Pelagic, and Seafloor/Demersal. Characterizing habitats in this way permits the selection and analysis of habitat-specific indicators. IEA Indicators for habitat types apply to multiple species associated with or dependent on that habitat type. This is intended to complement the extensive work already done under Essential Fish Habitat, which focuses on individual managed stocks and the habitats that they need for major life stages and processes.

3.3.2 Identify and document the contributions of inshore habitats to offshore fishery productivity

The Mid-Atlantic region is comprised of a mosaic of habitats extending from the rivers and estuaries to the continental shelf and beyond. These coastal habitats are used by most Council-managed species for spawning activities, nursery habitat, and refuge. Many forage species also use these coastal habitats. Activities occurring in freshwater and terrestrial habitats in the highly-developed coastal zone have downstream effects on coastal and estuarine ecosystems and contribute to the natural mortality of fishery species. However, limited information exists to quantify fisheries production resulting from inshore and coastal habitats, and this data is rarely incorporated in EFH identifications, descriptions, or maps.

Ecosystem models can help quantify the effects of habitat quality and availability on fish stocks, including effects on natural mortality, recruitment, growth, and migration. For example, ecosystem models have been used by NMFS to determine the contribution of marsh and oyster reef habitats in the Chesapeake Bay to summer flounder and black sea bass production, respectively.[11]

As described in section 3.1, EFH Source Documents include information on the coastal habitats used by Mid-Atlantic fisheries. Several additional data sources that can inform such ecosystem models are available from partner organizations, including:

- **National Oceanic and Atmospheric Administration (NOAA) National Environmental Satellite, Data, and Information Service (NESDIS) Coastwatch**: Satellite images and coast algorithms for chlorophyll, sediments, and sea surface temperature are useful for understanding the dynamics of coastal habitats.
- **Telemetry networks** (such as Atlantic Cooperative Telemetry Network and Mid-Atlantic Acoustic Telemetry Observing System): Data on fish movement patterns could be useful for understanding where fish prefer to spend time and movement patterns between inshore and offshore locations.
- **Otolith chemistry studies:** this type of analysis aims to identify stable isotope or trace element signatures that discriminate between locations where fish resided so information can be gained about the life history and movement of fishes. It provides a chronological record of exposure to habitats during natal and adult stages.
- **Research on the effects of stressors on habitat quality at the land/water interface** (such as the study in the Chesapeake and coastal bays conducted by scientists from The Smithsonian Environmental Research Center, Virginia Institute of Marine Sciences and University of Delaware): This type of work quantifies the connection between land use and shoreline alteration and the influence on estuarine and coastal habitats and ecosystems.

Updates to EFH Source Documents using these resources will improve our understanding of the location and functions of critical habitats. Additional work will be necessary to quantitatively link habitats and fisheries productivity.

[11] See: http://chesapeakebay.noaa.gov/ecosystem-modeling/chesapeake-bay-fisheries-ecosystem-model.

3.3.3 Recognize the impact of climate on habitat

Climate change and climate variability have been shown to cause changes in the physical attributes and biological dynamics of fish habitats. These changes can include:

- Ocean acidification (increases in dissolved CO_2 and decreases in pH) affects physiology, calcification, olfaction, and other biological components of individuals. Ocean acidification may also impact structured living habitat such as deep sea corals.
- Increases in temperature change the distribution of snow accumulation and the timing of snow melt, thus changing the timing and magnitude of streamflow.
- Increased temperatures also contribute to significant die-offs of submerged aquatic vegetation (SAV), important nursey habitat.
- Increases in precipitation lead to increases in streamflow and freshwater discharge into coastal systems. These changes in physical habitat will have direct (e.g., physiological) and indirect (e.g., through changes in survey availability) impacts on managed species.
- Increases in dissolved CO_2 may increase productivity of macroalgae and sea grasses, potentially increasing their capacity to provide shelter for managed species and their prey. However, increases in turbidity resulting from increases in streamflow may decrease macroalgal production.
- Sea-level rise will put pressure on nearshore habitats, particularly in areas where coastal hardening has occurred and natural marsh migration is restricted (Kirwan and Megonigal 2013). This may result in lost connectivity between adult, spawning, and nursery habitats used by fish species.
- Possible increase in storm intensity and frequency will also impact coastal habitats.

While the Council is limited in its ability to control the effects of climate change on fish habitat, these impacts should be carefully considered as the Council works to address habitat conservation from an ecosystem perspective.

3.3.4 Strengthen EFH designations and consider "essential" from an ecosystem perspective, emphasizing connectivity between species, life history stages, etc.

To date, EFH designations have been considered on a single species basis. This has proven useful for regulatory purposes, but there is a need to consider habitat more broadly from an ecosystem perspective at regional and global scales to enable more integrated management of overlapping and interacting fisheries. Moving toward ecosystem-level habitat description and conservation will require consideration of habitat from new perspectives and at different scales relative to historical practice.

Consideration of EFH designations from an ecosystem perspective will require evaluation of habitat use for multi-stock assemblages. It must be acknowledged that the marine ecosystem is comprised of a complex system defined by prey abundance/distributions and multi-species interactions with habitat. This could be accomplished through the development of multi-species EFH/habitat designation for both managed and other ecosystem species (including individual species and combination of species in similar trophic levels, guilds, and/or stock complexes). In addition, indicators of habitat status for stock complexes need to be identified and evaluated.

Overall, the Council needs to find practical approaches to begin describing and addressing habitat based on metrics that are easy to measure and document. This should include temperature as an environmental factor in both stock assessments and EFH designations. Modeling techniques need to be applied to existing data to improve EFH designations based on the most recent time series data while also considering seasonal effects.

The Council also should consider taking a layered approach to applying habitat support tools. Designating EFH based on stock complexes may make the most sense from an ecosystem perspective, but this approach could complicate the EFH consultation process. The EFH text descriptions need to be simple to support NMFS permit consultations, with a broad trigger for a consultation followed by a detailed evaluation of a proposed action's impacts on habitat.

It is important to acknowledge the limitations of EFH designations. Because they are largely based on trawl survey data, many important and productive areas of fish habitat are not sampled and are therefore not always reflected in EFH descriptions. For example, the NEFSC trawl survey does not systematically sample within estuaries and the continental margin, which are areas of high productivity that support critical life stages of managed and forage species.

3.3.5 Quantitatively link habitat science and conservation to fishery outcomes, focusing on ecosystem resilience and productivity

Studies of reproduction, survival, and productivity of species within their habitats need to be linked to overall ecological productivity. Temperature is easy to measure and is one of the most basic biological metrics to use as a starting point in habitat science. Other important attributes include predator and prey migration (onshore-offshore, vertical), light regimes, dissolved oxygen, primary production, reproduction, survival, growth, and ocean acidification. Changes in the magnitude and directionality of these factors can lead to shifts in trophic interactions.

In the Mid-Atlantic region structured habitat may be particularly important given the prevalence of featureless habitat throughout the region (sand, mud and silt). The lack of fishery-independent survey sampling near structured habitat limits our ability to define and evaluate these types of habitat. Also, the uniformity of habitat types throughout the Mid-Atlantic region limits our ability to describe the dynamics of habitat types through mapping. Habitat assessment prioritizations are being conducted by the NEFSC to prioritize species habitat and stock assessment research.

3.3.6 Determine if existing habitat authorities are being fully utilized and provide guidance to improve efficacy of EFH consultation

The Council attempts to minimize impacts to EFH for non-fishing activities through the consultation process and by evaluation and implementation of measures to reduce fishing impacts. To improve the efficacy of this process, the Council needs to work with its management partners to identify projects that may adversely affect EFH for Council-managed species. The Council should also develop formal habitat policies to expedite the process of commenting on projects of concern. The Council should consider how to most effectively engage its advisors in this process. Finally, the Council needs to prioritize areas for habitat identification and/or protection from fishing and non-fishing activities and identify goals and criteria for designating HAPCs.

3.3.7 Identify research needs and goals to support Council habitat mandates and decision-making needs

In order to incorporate habitat considerations more effectively into EAFM, the Council has identified a number of habitat-related research needs and opportunities for better utilizing existing habitat data. These are described below.

- Much of the current scientific information is based on broad trawl survey work, which has the advantage of very extensive coverage but at a coarse scale. Targeted habitat-based sampling needs to be greatly expanded to provide data beyond the current trawl sampling. This would allow for characterization of important habitats in areas where sampling is currently limited or nonexistent.

- The current time series data should be updated, and improved analyses and modeling should be applied to existing data sources, including spatial analyses at finer scales.
- The Council should support new technologies to find better ways of collecting habitat information.
- The locations of different habitat types need to be identified, and their impacts on growth rates and other vital population parameters should be incorporated into stock assessments.
- The Council should support targeted habitat mapping in areas of most critical habitat based on standardized approaches of collecting and processing the data. (e.g., multibeam in shallow water, side scan, lidar in shallow water).
- Criteria and metrics for the successful management of habitat need to be identified, similar to stock-based metrics like overfished and overfishing.
- The impacts of habitat loss and degradation need to be more fully integrated into the fishery management process.
- The Council should continue to consider measures which minimize the impacts of fishing and other activities on habitat, including ways to incentivize habitat protection.
- In general, new data sources could be used to update and refine current habitat information and improve our understanding of fish habitat use.

As the Council and its partners work to address these habitat research needs, the following possible long-term habitat goals should be considered 1) quantify fishing impacts and reduce the footprint of impact, 2) develop productivity set aside areas, 3) identify priority stressors on habitat for key species and find ways to reduce those stressors, and 4) identify priority areas for multi-species habitat protection (possibly HAPCs).

4. Climate Change and Variability

4.1 Background

Fishermen and fishery managers have already observed climate-related changes in some East Coast fisheries. As the marine environment becomes warmer and more acidic, some species have shifted north, moved offshore, or exhibited changes in productivity and recruitment. For the Mid-Atlantic Council, "climate readiness" has involved an explicit and strategic focusing of attention on coordination with other East Coast fishery management partners. In 2014, the Council hosted two climate workshops – the first focused on the current state of climate science and the potential impacts of climate change on marine ecosystems, and the second addressed the management and governance implications of climate change.

The results of the two workshops are synthesized in the Council's white paper on Climate Change and Variability.[12] The paper was designed to frame our understanding of the impacts of climate change and variability on marine resources under the management purview of the Council, including implications for marine ecosystems, fish stocks, fishery management and the communities and economies that depend on them. Having a reasonable understanding of the future state of ecosystems in the Mid-Atlantic in response to climate change and variability is a fundamental prerequisite to the development of management policies that will allow for the achievement of the Council's vision for the future of the fisheries which exist within those ecosystems.

4.2 State of Climate Change in the Mid-Atlantic

The Northeast region is experiencing profound changes in physical and oceanographic properties as a result of both natural climate variability and human-induced climate change. The region is experiencing one of the fastest increases in average temperature observed globally with ocean temperatures increasing by 1.3°C since 1854 coupled with ocean acidification and increased rates of sea level rise. Climate projection models predict continued increases in temperature, decreases in salinity increases in precipitation, decreases in pH and continued sea level rise.

There are multiple potential biological responses to the pressures of climate change and variability. In general, the anticipated pressures that could affect fisheries in the Northwest Atlantic basin include:

- Warmer water,
- Changing volume of thermal habitat,
- Shifting local hydrography (e.g., fronts, local winds and currents),
- Changing large scale hydrography (e.g., altered boundary currents),
- Changing water chemistry (fresher, more acidic, lower oxygen),
- Changing primary production and other bottom up forcing,
- Changes in species composition (including invasive species or native species from other regions), and
- Changes to habitat, including loss of deep sea coral and of coastal wetlands.

At the community or population scale, the basic biological attributes regulating population fluctuations (and therefore of interest to fishery management) include productivity, physiology, process timing or phenology, ecological context (primarily predator-prey and competitive interactions with other species), and spatial distribution (both range and center).

[12] See http://www.mafmc.org/s/MAFMC-Climate-Change-and-Variability-White-Paper_Apr2015.pdf

Numerous studies have demonstrated long-term changes in the distribution and productivity of fish and shellfish resources on the Northeast U.S. Shelf. Changes in distribution have been documented in a large number of populations. Fewer studies have examined changes in stock productivity. The role of climate-forced changes in predator-prey dynamics needs to be investigated, but large-scale changes in species compositions suggests large-scale changes in predator-prey dynamics. Climate change and variability will also impact protected species and thereby change the interactions between protected species and fisheries.

Important fisheries population dynamic parameters such as growth rates, natural mortality and recruitment are all likely to be vulnerable to climate change. Stock assessments models are highly dependent on these parameters. Consequently, changes in these parameters will likely result in changes to biological reference points that are used in stock assessment. Stock assessment models that treat models that explicitly incorporate environmental drivers have the potential to adapt much more quickly and more accurately represent changing stock dynamics.

Assessing the impacts of climate change on recreational and commercial fishermen and their communities consists of assessing the current composition of fisheries, and understanding the likely social, cultural, and economic dynamics accompanying the biological and ecological changes expected to occur. There are a number of economic models available that can evaluate changes in landings, income, employment and trade-offs between revenue streams due to species distributional shifts (Steinback and Thunberg 2006; Jin et al. 2014). In addition, spatial modeling of fishing location choice will also play an important role in assessing impacts and predict responses for both commercial (Haynie and Layton 2010) and recreational fishermen (Jarvis 2011).

The longer-term impacts of climate change are more problematic to assess because they necessitate the use of data not currently gathered by NMFS on a regular basis or require model predictions out of sample. Further, management based on species/area combinations – whether the division of FMPs across regional fishery management councils, the placement of closed areas for spawning grounds, or the assignment of Individual Transferable Quotas (ITQs) to specific areas – will need updating as species change location. These types of pressures are already being seen in allocations that are made on a state-by-state basis based on historical landing patterns. In some cases, species will increase or decrease stock levels, again requiring management adjustments. The resolutions of these governance issues are strongly tied to social and economic impacts and the demographic and preference data referenced above will be critical in predicting and assessing those impacts. Ultimately, a more robust understanding of the long-term dynamics expected to occur due to climate change would necessitate additional investment in socio-economic data and research.

4.3 Climate-Related Policy Statements

The Council adopted the following policy statements related to incorporating climate considerations into the current management system:

1. **Continue to work with NOAA on the implementation of the NMFS Climate Science Strategy in the Northeast region.**
2. **Develop and evaluate approaches for MAFMC fisheries and their management to become more adaptive to change.**
3. **Continue to advocate for, collaborate on, and support historical field and laboratory research to understand the effects of climate change on species managed by MAFMC and incorporate those results into assessment and management.**

4.4 Climate Science Initiatives

Climate-ready fisheries management requires having the science, governance structure, management tools, and political will to make challenging decisions in a changing environment (Pinsky and Mantua 2014). There are multiple points for climate science information to enter living marine resource management processes that encompasses science and research as well as assessment, advice, and management decision making. Here in the Mid-Atlantic region, we start with data collection and population modeling on the science and research side, then go into a review and status determination process during the stock assessment and advice stage. A critically important part of this process is the continued research and continued collection of data related to the effect of climate on marine resources.

4.4.1 Risk Assessment – Northeast Fisheries Climate Vulnerability Assessment

Risk assessment is a valuable tool to apply even before attempting to incorporate climate science information into specific stock assessments and management advice (Gaichas et al. 2014, Hare et al. 2016). Because multiple stocks are under management, a risk assessment framework provides a useful tool for identifying both priority risks and priority stocks requiring detailed analysis. For the Mid-Atlantic region, a recent simple risk analysis applied to benthic, pelagic, and demersal fish and invertebrate communities found that commercial and non-target benthic invertebrates might be among the most sensitive species to short term predicted and observed climate impacts in the region (Gaichas et al. 2014).

The following section outlines a potential framework for incorporating climate science within stock assessments and fisheries management. This approach attempts to make the best use of available tools, information, and time. Using risk assessment as a first step, limited scientific resources may be focused on a subset of high-priority stocks, and climate impacts can be examined with more detailed individual assessments. It is important to begin with a big-picture assessment of the economic and social importance of the stock as well as its particular vulnerabilities to the observed and projected climate variability or change.

The Northeast Fisheries Climate Vulnerability Assessment (NEVA) is an extensive analysis of the climate vulnerability of 82 fish and invertebrate species in the Northeast region (Hare et al. 2016). The NEVA uses existing information on climate and ocean conditions, species distributions, and life history characteristics to assess relative vulnerability to changes in species abundance under projected future climate and ocean conditions. For Council-managed species, ocean quahog was identified as being very highly vulnerable to climate change, and three species (tilefish, Atlantic surfclam, and black sea bass) were highly vulnerable to climate change (Figure 3). The remaining species had moderate or low vulnerability to a change in abundance and productivity due to climate change. A vast majority of Council-managed species had a high or very high potential for changes in distribution (12 of 13 species[13]); only golden tilefish had a low potential for a change in distribution (Figure 4). Overall, the impacts of climate change are expected to be negative for three Council-managed species (Atlantic mackerel, Atlantic surfclam, and ocean quahog), whereas the impacts are expected to be positive for six species (black sea bass, scup, butterfish, longfin inshore squid, Northern shortfin squid (*Illex*), and bluefish; Figure 5). The effects of climate change are expected to be neutral for the remainder of Council-managed species.

[13] As of the time of this analysis, blueline tilefish was not managed by the Council, but has since been added as a Council-managed species.

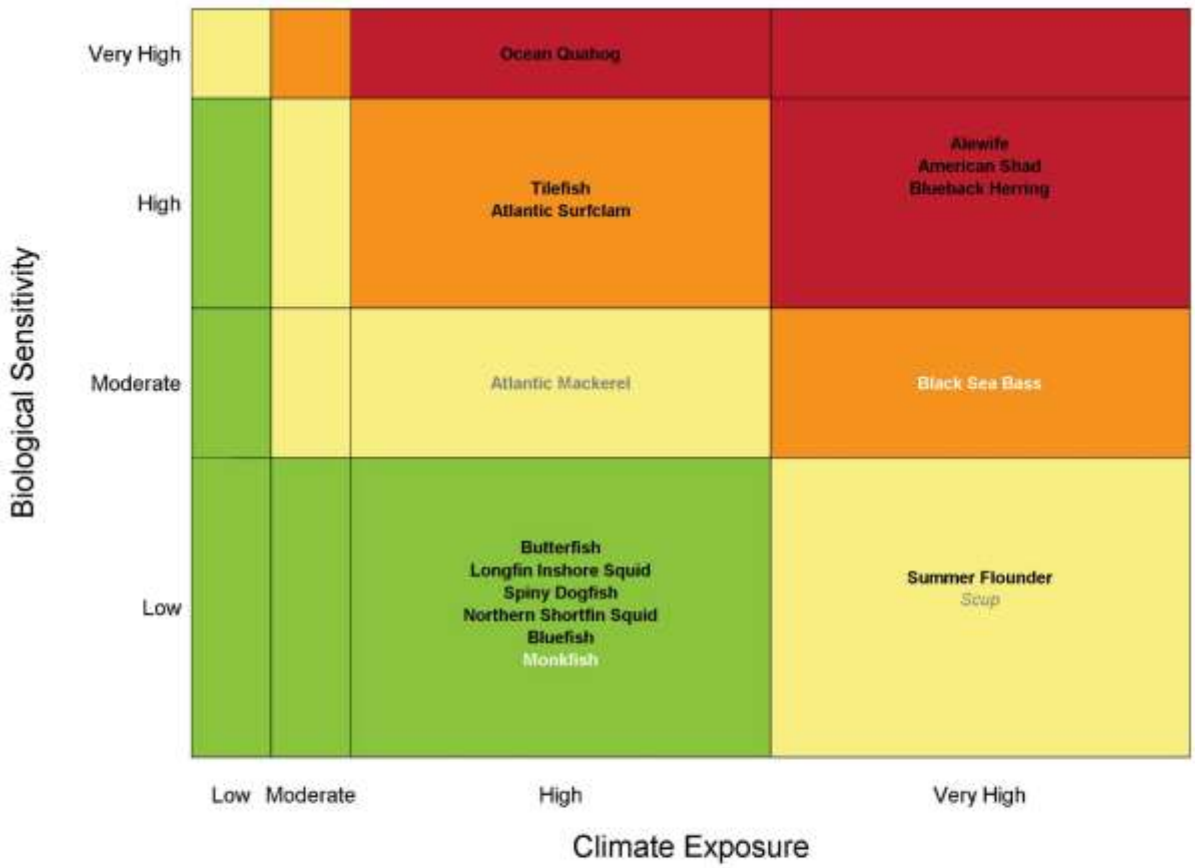

Figure 3: Summary of results from the Northeast Fisheries Climate Vulnerability Assessment for Council-managed species. Overall climate vulnerability is denoted by color: low (green), moderate (yellow), high (orange), and very high (red). Certainty in score is denoted by text font and text color: very high certainty (>95%, black, bold font), high certainty (90-95%, black, italic font), moderate certainty (66-90%, white or gray, bold font), low certainty (<66%, white or gray, italic font) (adapted from Hare et al. 2016).

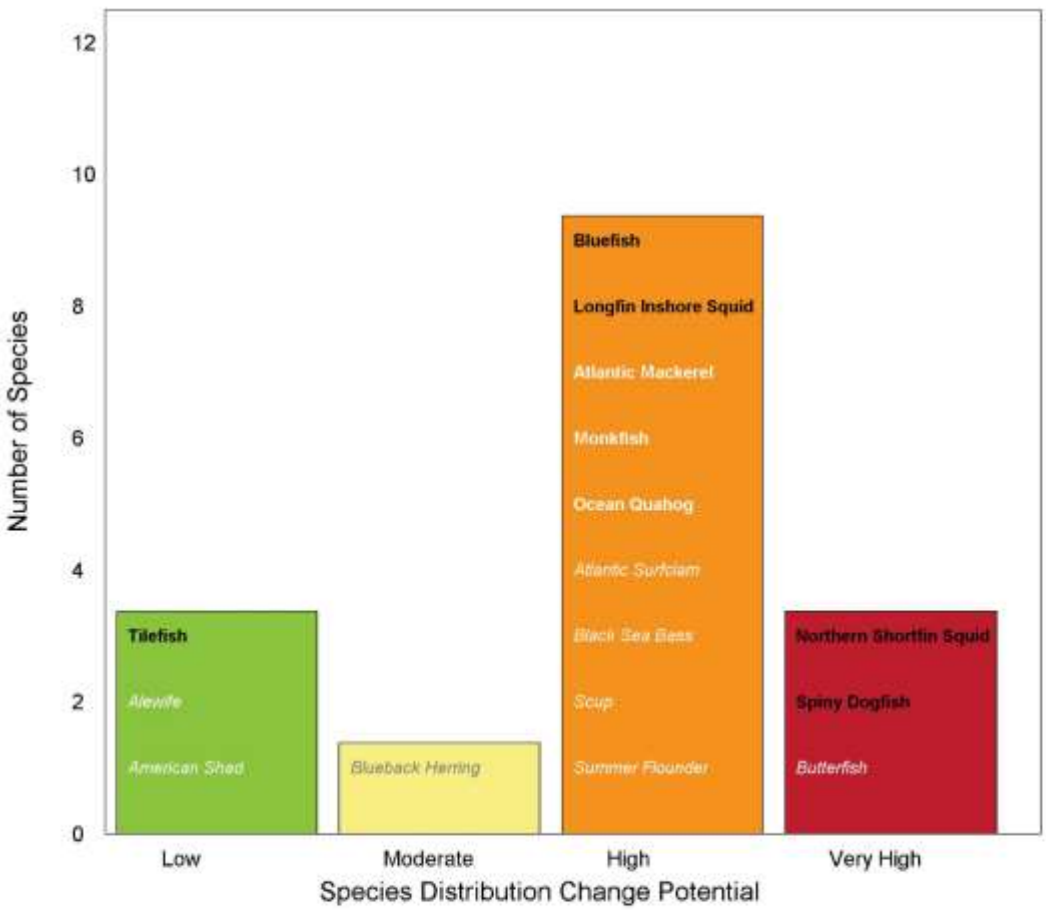

Figure 4: Northeast Fisheries Climate Vulnerability Assessment – Potential for a change in species distribution for Council-managed species. Potential was calculated using a subset of sensitivity attributes. Colors represent low (green), moderate (yellow), high (orange) and very high (red) potential for a change in distribution. Certainty in score is denoted by text font and text color: very high certainty (>95%, black, bold font), high certainty (90-95%, black, italic font), moderate certainty (66-90%, white or gray, bold font), low certainty (<66%, white or gray, italic font) (adapted from Hare et al. 2016).

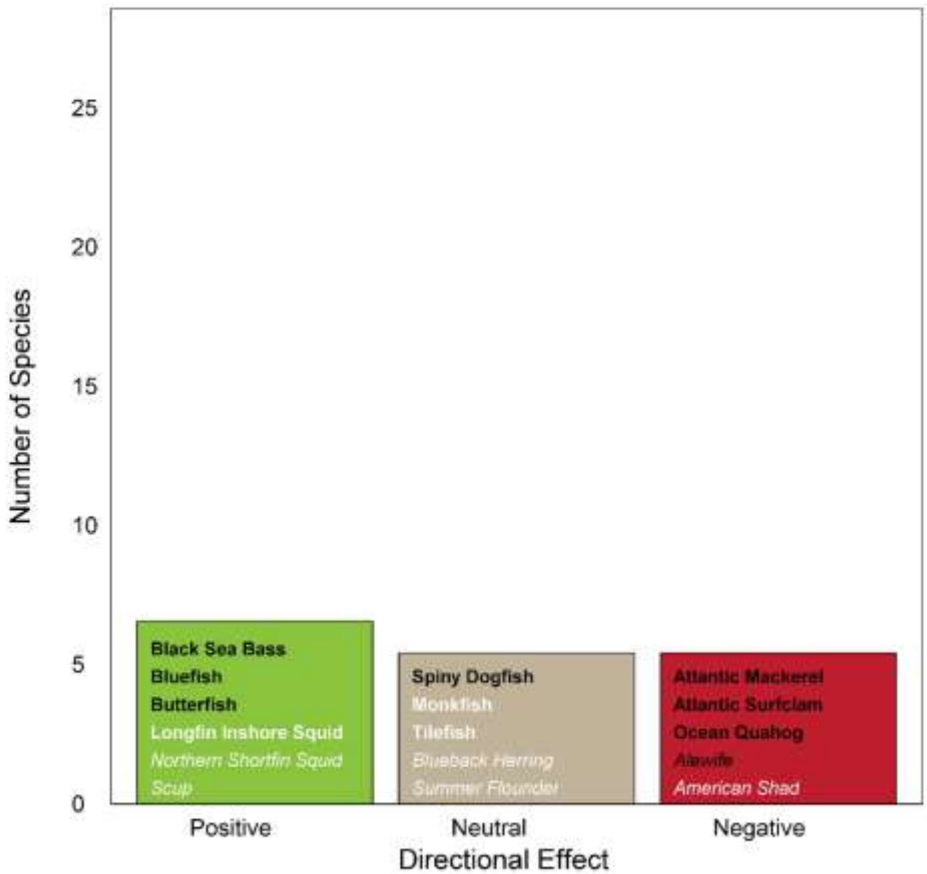

Figure 5: Northeast Fisheries Climate Vulnerability Assessment – Directional effect of climate change for Council-managed species. Colors represent expected negative (red), neutral (tan), and positive (green) effects. Certainty in score is denoted by text font and text color: very high certainty (>95%, black, bold font), high certainty (90-95%, black, italic font), moderate certainty (66-90%, white or gray, bold font), low certainty (<66%, white or gray, italic font) (adapted from Hare et al. 2016).

The assessment indicated that changes in distribution will present the largest management challenge to the Council, while changes in productivity are likely to be less pronounced. The management responses to species positively affected by climate change should also be considered by the Council. The vulnerability assessment also developed species-specific information (see Hare et al. 2016) that should be considered when developing management strategies and determining future research priorities.

4.4.2 Future Distribution Shifts and Fishery Impacts

Additional information to guide the Council's future policy with respect to climate interactions is described in a collaborative peer-reviewed publication titled "Projecting shifts in thermal habitat for 686 species on the North American continental shelf" (Morley et al. 2018). The purpose of this research was to inform the Council about the rate, magnitude, and uncertainty surrounding future distributional changes for managed and other important species likely to occur as a result of climate change over the next several decades and for the remainder of this century. This work builds upon the NEVA's initial work on likely range shifts to rank species by the rate and magnitude of range shift as well as the uncertainty in those values, while also diagnosing the dominant sources of uncertainty. In collaboration with the Council, this work identifies potential priority species for adaptation of fisheries management to climate change. This is intended to further clarify risks to the Council's management objectives and identify future issues likely to arise from climate-driven distributional shifts.

4.5 Recommendations for Incorporation of Climate Change and Variability Factors into the Current Stock Assessment and Fishery Management Process (A *Climate-Ready Check List*)

Based on the considerations described above, the following list of actionable items has been identified by the Council for incorporation of climate considerations into the current stock assessment and fishery management process:

1. **Continue to work with NOAA on the implementation of the NMFS Climate Science Strategy in the Northeast region.[14]**
2. **Re-evaluate stock identification of Council-managed species - a Working Group could be established modeled after the International Council for the Exploration of the Sea (ICES) Stock Identification Methods Working Group.**
3. **Identify new species likely to become established in the Mid-Atlantic (from the South Atlantic) and species likely to expand or shift distribution into waters under the jurisdiction of New England and Canada; evaluate current monitoring program relative to these species and consider potential management responses to developing fisheries.**
4. **Develop and evaluate approaches for MAFMC fisheries and their management to become more adaptive to change.**
5. **Incorporate temperature into all Council-managed species stock assessment models; consider incorporation of other environmental factors where appropriate; use models to develop short-term forecasts and medium-term projections.**
6. **Evaluate changing interactions of Council-managed fisheries with protected species including marine mammals, sea turtles, and fish species.**
7. **Conduct industry, management, and scientist workshops before benchmark assessments are scheduled. Workshops should build off the butterfish and Atlantic mackerel workshops.**
8. **Continue to engage industry and identify other platforms of opportunity (academia, state sampling programs, etc.) in the oceanographic and fisheries monitoring and research in the Mid-Atlantic region.**
9. **Continue to advocate for, collaborate on, and support historical field and laboratory research to understand the effects of climate change on Council-managed species.**
10. **Repeat the Northeast Fisheries Climate Vulnerability Assessment in conjunction with the International Panel on Climate Change Assessment Report 6 (recently updated CO_2 emission and climate change scenarios).**
11. **Provide input to the NEFSC on elements of the Annual State of the Ecosystem report to meet Council needs.**
12. **Develop MSE capacity to support EAFM activities of the Council. The MSE framework should explicitly evaluate management strategies to meet Council goals in response to climate change (as well as habitat, species, social, and economic interactions).**

[14] For more information please see: https://www.st.nmfs.noaa.gov/ecosystems/climate/national-climate-strategy

5. Ecosystem-Level Interactions

This section provides a synthesis of approaches to deal with the complex ecosystem interactions considered by the Council throughout the development of the EAFM Guidance Document. The information provided in this section is largely derived from information presented and discussed at a workshop convened by the Council to discuss potential strategies to more fully consider interactions in the stock assessment and management process (including determination of catch limits) and to build capacity within the region to conduct comprehensive management strategy evaluations (MSEs). A complete summary of the workshop and its findings can be found in the Species Interactions White Paper.[15]

Section 5.1 describes the Council's policy statement on evaluating ecosystem-level trade-offs, including social and economic considerations. Section 5.2 describes existing single-species approaches as well as information and analytical tools available to address key interactions between species and their environment, between species within the food web, between the ecosystem and fisheries, and between fleets due to technical or management issues. Based on these approaches and tools, as outlined in section 5.3, the Council has developed a proposed framework and process for defining key questions, evaluating the adequacy of information and analytical tools to address the questions, and developing analyses to evaluate management strategies to achieve the Council's ecosystem-level management objectives.

5.1 Ecosystem-Level Policy Statement

Recognizing the importance of integrating biological, ecological, social, and economic considerations into management decisions, the Council adopted the following policy:

> **The Council, in conjunction with its SSC and the NEFSC, shall promote the timely collection of data and development of analyses to support the biological, economic, and social evaluation of ecosystem-level trade-offs, including those required to establish an optimal forage fish harvest policy.**

This policy statement is important because, historically, fishery management under the MSA has focused primarily on the biological aspects of fishery conservation and management. An examination of current practices relative to the incorporation of social and economic analyses in federal fisheries management occurred at the fourth national SSC workshop. The results of that workshop emphasized the need to greatly improve social and economic impact analyses and incorporate them in federal fisheries management (Seagraves and Collins 2012). Little has changed in this regard since that workshop was held in 2011. To address this deficiency, the Council should consider the formation of a working group comprised of Council and NOAA Fisheries Regional office staff, NEFSC personnel, and SSC members with expertise in the social and economic disciplines. The Council's SSC has recently discussed a desire to increase engagement of its members with expertise in the social and economic disciplines, so the environment is favorable for the adoption of this approach. The Council should establish terms of reference for the working group which directs the group to evaluate available information and recommend a prioritized economic and social research plan to address the forage fish trade-off issue, as well as other ecosystem considerations identified in this document.

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[15] See http://www.mafmc.org/s/MAFMC-Interactions-White-Paper_Jan2016.pdf

5.2 Approaches to Evaluate and Address Ecosystem Interactions

The Mid-Atlantic region has considerable available resources for addressing interactions, in terms of both available data and analytical tools. There is a wealth of environmental, ecological, and social and economic data that could potentially be integrated into analyses to support management decisions. An overview of available information (but not an exhaustive list) is synthesized in the NEFSC Ecosystem Status Report (ESR; available at http://www.nefsc.noaa.gov/ecosys/ecosystem-status-report/sitemap.html). Despite this wealth of data, information to address particular interactions may be sparse, such that information needs should be evaluated for each management issue, and uncertainties arising from missing information should be considered, as is current practice.

A spectrum of assessment and modeling methods are available to assist the Council with incorporating species, fleet, and climate interactions into management. Models range from conceptual to statistical and mechanistic mathematical models, from single species population dynamics to integrated ecosystem assessment, and from tactical to strategic. Ultimately, the Council will need to prioritize which interactions to deal with first, and risk assessment methods can contribute to this decision process. Similarly, the Council will need to evaluate management strategies to determine how they perform in achieving Council objectives, as well as evaluate trade-offs between those objectives, which may be inevitable when considering a range of interactions and possible outcomes. A combination of these tools designed to address particular interactions can be developed for each management issue as with data above, as is also current practice.

5.2.1 Single Species Stock Assessments

In many ways, environmental, species, and fleet interactions are already accounted for in current stock assessments, depending on data inputs and model configuration. For example, single species stock assessments that use changing weight-at-age data over time as input are incorporating the effects of a changing environment and ecology on fish growth, although the sources of this variation cannot be identified. Further, some assessments incorporate changes in natural mortality (M) over time which can represent changing species interactions (most often, predation), but could also represent habitat or other environmentally mediated changes. Some effects of technical interactions between fisheries are included for individual species using the Standardized Bycatch Reporting Methodology (SBRM) to ensure that mortality from both directed fisheries and incidental catch are accounted for in assessments.

Successful fishery management can make the effects of interactions more important. As mortality due to fishing declines, natural mortality becomes a more important fraction of total mortality and therefore more influential on population dynamics. Reductions in fishing mortality also tend to increase lifespan and reveal traits obscured by high exploitation. To understand dynamics for rebuilding depleted stocks requires multiple disciplines, including population biology and ecology as well as bio-economics, ecological and environmental change. Forecasting these changes can be challenging, but some key research at the interface of these disciplines can help.

Determination of absolute abundance is the greatest challenge for single species, multispecies, and ecosystem models. To address this challenge, managers and scientists should foster an environment where there is increased interaction between gear technologists and stock assessment scientists (see e.g. Somerton *et al.*, 1999). Within a single species model, the ability to estimate changes in natural mortality (M) is dependent on the ability to fix the quantity scaling the fishery independent index of population size to absolute population size (Q or survey catchability).

5.2.2 Trophic and Multispecies Interactions

Models intermediate in scale between single stock and full ecosystem may be most promising in terms of providing tactical advice that incorporates species and fleet interactions as well as some environmental factors (Collie *et al.*, 2014; Plagányi *et al.*, 2014). Multispecies models are in development for the Northeast U.S. shelf to extend the suite of modeling tools available for assessment of species and fleet interactions (e.g., Curti et al. 2013; Van Kirk et al., 2015). A suite of multispecies and ecosystem models already exists in this region, with several more currently in development. These existing models range from spatially explicit bio-geochemical ecosystem models, multispecies production models, age-structured predator-prey models, and single species models extended to include predators. A prototype multispecies assessment project has been initiated for Georges Bank, which incorporates multispecies production models, multispecies delay difference models, and empirical nonlinear time series forecast models as assessment models within a multi-model inference framework. This process both improves the multispecies models and informs managers of their strengths and weaknesses**.** Based on this work, multispecies models can be designed and evaluated for Mid-Atlantic stocks where appropriate.

Other approaches under development include several static mass-balance food web models. Food web models are useful for estimating the relative proportion of fishing and predation mortality to evaluate whether assessments should consider including variable predation mortality. Food web models also quantify major prey for key species and can be used to evaluate whether assessments should consider including food-limited growth when prey fluctuate. Food web models exist for four regions of the Northeast U.S. shelf, including the Mid-Atlantic, Southern New England, Georges Bank, and Gulf of Maine (Link *et al.*, 2008, 2009). Updated models with more detail for individual species in each region and multi-fleet fisheries are currently under construction.

While many of these multispecies models and food web models have an established role in providing strategic advice, the current challenge is to provide tactical management advice for fisheries in a multispecies context that can be readily used within the existing management framework. The NEFSC is developing a system of simulation and assessment models to meet this challenge.

In addition, approaches that consider fleet interactions and the social and economic linkages across species in order to evaluate economic risk-reward trade-offs of multispecies fishery management are also being developed. Fishery interactions across species have the potential to greatly impact fishing behavior, with implications for both human and marine communities (for example, yellowtail flounder as bycatch in the scallop fishery). In the context of EAFM, the tools currently available for assessing fleet interactions are high level, due to the complexity of the interactions, and generate indicators that can be tracked over time. Portfolio analyses identify the mix of species that maximize the probability of achieving the targeted returns to a system in any given year. Portfolio analysis as developed in Jin *et al.* (2016), and following Sanchirico *et al.* (2008), can be used to assess historical performance of Council-managed fisheries by comparing the realized level of risk to the minimum risk that could have produced the same level of returns. These analyses can also be coupled to the multispecies models currently under development at the NEFSC to provide an explicit evaluation of risk-reward trade-offs for future scenarios. Given that returns are not the only objective of management, the portfolio analysis would allow an understanding of the cost, in terms of additional economic risk, of achieving a suite of management objectives.

5.2.3 Integrated Ecosystem Assessments for Northwest Atlantic Ecosystems

As described in section 3.3.1, an IEA is an approach to Ecosystem-Based Management which integrates all components of an ecosystem, including humans, into the decision-making process so that managers can balance trade-offs and determine what is more likely to achieve their desired goals. The Northwest Atlantic region has well-developed ocean observation systems, marine ecosystem surveys and habitat studies, though social and economic data collection systems are less well developed, and steps are being taken throughout the region to organize existing information and effectively communicate it to stakeholders and decision-makers. A visualization of the IEA framework as developed by NOAA is provided in Figure 6.

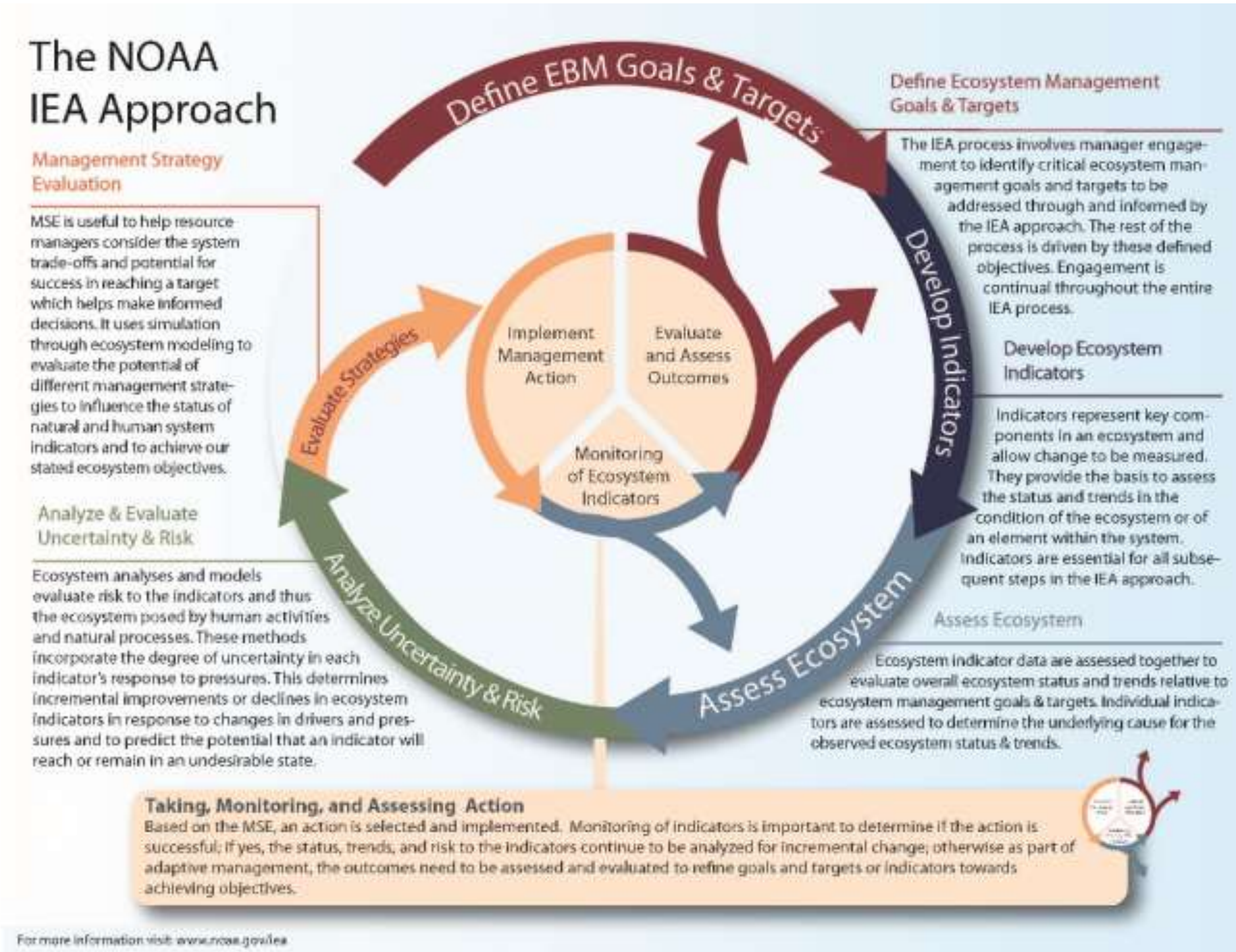

Figure 6: A visualization of the IEA approach, as developed by NOAA.

Work is underway in a variety of contexts around the North Atlantic to develop IEA methods and approaches to support an EAFM. For example, the International Council for the Exploration of the Seas Working Group on the Northwest Atlantic Regional Sea (ICES WGNARS) is comprised of scientists and managers from Canada and the U.S. The overarching objective of WGNARS is to develop IEA capacity in the Northwest Atlantic region to support ecosystem approaches to science and management. Considerable work has already been done compiling and reviewing ecosystem indicators across the themes of climate, biodiversity and habitat. Social sciences were integrated within the group early on, and the group continues to work on more fully integrated ecological and human dimensions in IEAs. Issues of spatial scale are important because the Northwest Atlantic Regional Sea encompasses a variety of diverse ecoregions across a wide range of latitudes, physical oceanographic regimes, and habitats, as well as multiple administrative and management jurisdictions and boundaries, sociocultural groups and regional economies.

In addition, NOAA's IEA program[16] recently completed an updated Northeast U.S. Ecosystem Status Report, an entirely web-based product available at http://www.nefsc.noaa.gov/ecosys/. Relative to previous releases, this version features an expansion of human dimensions, stressors and impacts, status determination, and summary sections. The summary section can also be provided as a stand-alone annual "state of the ecosystem" report. Plans are in place to develop cumulative impact analysis and a marine ecosystem services assessment index, which would assign numerical scores for the status of delivery of a suite of ecosystem services that we've identified. Research continues into identifying regime shifts, and in multispecies and ecosystem modeling.

5.2.4 Conceptual Models

"Conceptual models" developed for the California Current IEA are being adapted for the Northeast U.S. shelf, and could be a useful tool for the Council to address species and fleet interactions. Conceptual models are intended to provide a unifying framework that crosses disciplines, and clarifies system boundaries and any gaps in knowledge (Heemskerk *et al.*, 2003; Orians *et al.*, 2012). They are invaluable as a communication tool within an IEA working group, with other scientists, and with the public. This frame-work allows linking of indicators with elements of the conceptual models, as well as linking concepts across ecological and social components of a given system. The California Current IEA project worked for over a year to produce a set of linked conceptual models in December 2014, as illustrated in **Error! Reference source not found.**a and 7b.

In developing these conceptual models, the IEA team looked at each focal ecosystem component to develop links between ecological interactions (e.g. what are the strongest food web interactions), environmental drivers (what are the acknowledged drivers of abundance and community composition?), human activities (what are the strongest known human interactions or human risks posed to this focal ecosystem component?) and human wellbeing (what is the human dimension context?). Detailed linkage models were developed for six ecosystem components: salmon species, coastal pelagic species, groundfish species, marine mammals, seabirds, biodiversity, and habitat. The California Current IEA project has used these conceptual models to improve communications with regional fishery management councils regarding key linkages between managed species and the environment, in groundfish stock assessment ecosystem considerations sections, and on their webpages for navigation by users to see linked information on status, trend, indicators, etc.

[16] www.noaa.gov/iea

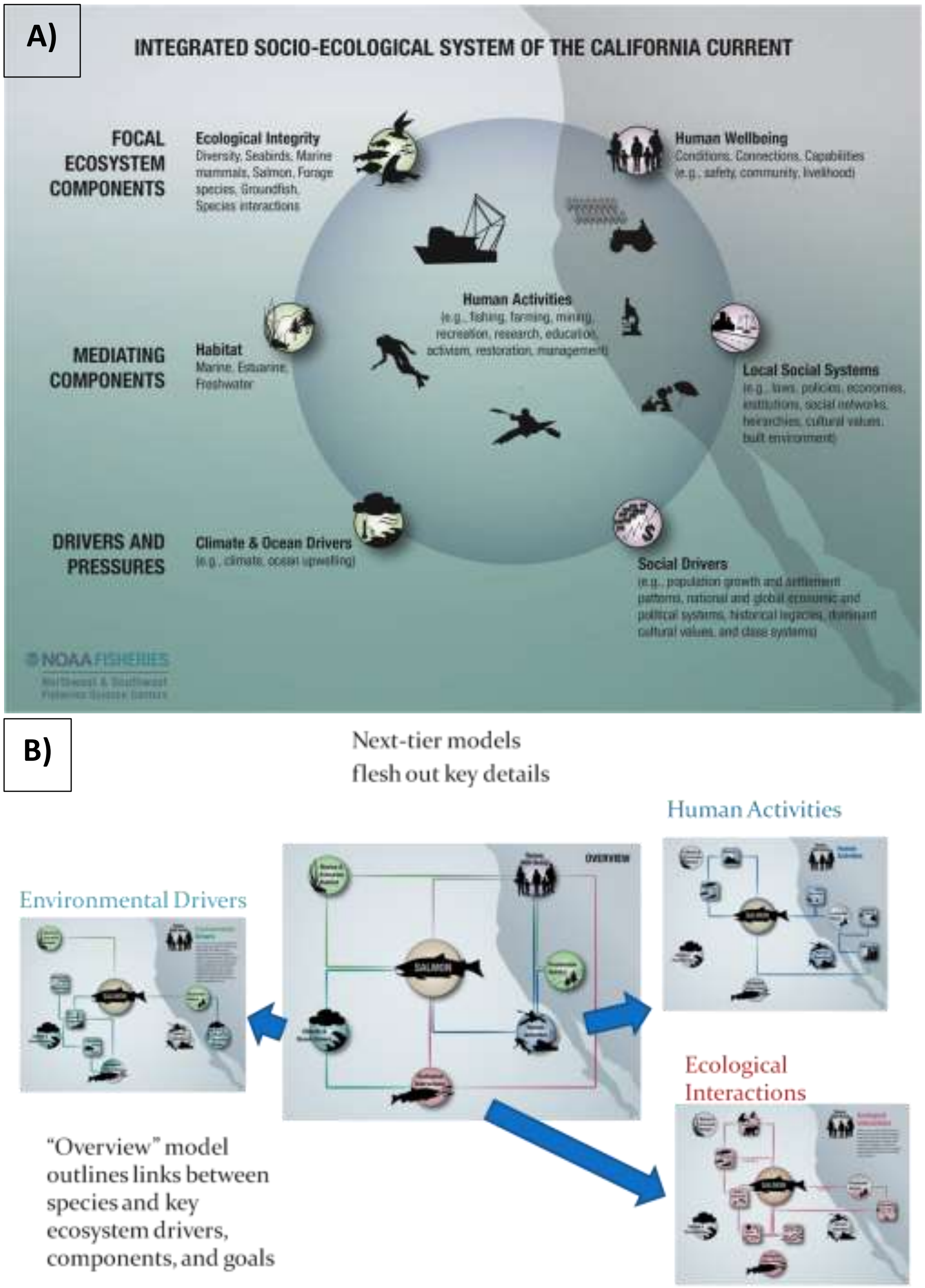

Figure 7: A) Overall California Current system IEA model linking environmental drivers, human activities, and ecological interactions for key ecosystem components. B) A nested conceptual model of the California Current ecosystem, centered on salmon. The overview illustrates relationships to key environmental drivers; ecological interactions; and human activities.

5.2.5 Management Strategy Evaluation

Management decisions are always made with substantial uncertainty. For example, there is uncertainty in the estimate of the status of the resource, the population dynamics of the resource, and the effects of the management decision on the resource and on the system as a whole. There is also uncertainty and risk associated with management choices. Management Strategy Evaluation (MSE) is an approach to determine if a method for making decisions is likely to achieve specified objectives (e.g., Butterworth, 2007; Punt *et al.*, 2014; Smith 1994; Smith *et al.*, 2007). The MSE approach requires objectives be specified, performance metrics be identified, and management strategies, scenarios, and uncertainties to be specified clearly, and then uses a simulation model to test each management strategy's ability to meet the specified objectives.

An important aspect of MSE is that defining the objectives, performance metrics, and key uncertainties should be done within an inclusive stakeholder process. MSE is a simulation analysis, but to be helpful with management decisions, framing the analysis and the control rules or other management procedures to test must include managers, policy makers, fishermen, scientists, and other stakeholders. Overall, MSE allows the Council an opportunity to test management measures before implementation. MSEs can be particularly good for identifying strategies that will not work. MSE should be considered an investment rather than a quick fix, because the time requirement can be long and MSE is inherently an iterative process. Further, not all important uncertainties and objectives can be explicitly included, and MSE results can be highly dependent on the assumed dynamics. Therefore, investment in multiple simulation models with adequate alternative structures to evaluate the interactions of interest (species, habitat, climate and fleet) is a pre-requisite for effective MSE.

5.3 EAFM Structured Framework

The Council agreed to adopt a structured framework approach, discussed in greater detail below, in order to incorporate species, fleet, habitat, and climate interactions into management. This approach would first prioritize fishery ecosystem interactions, second specify key questions regarding high priority interactions, and third tailor appropriate analyses to address them. The primary tools for these initial steps in the structured framework are risk assessment and MSE. Finally, implemented management measures would be evaluated to ensure that objectives are being met, or to adjust measures as conditions change (Figure 8).

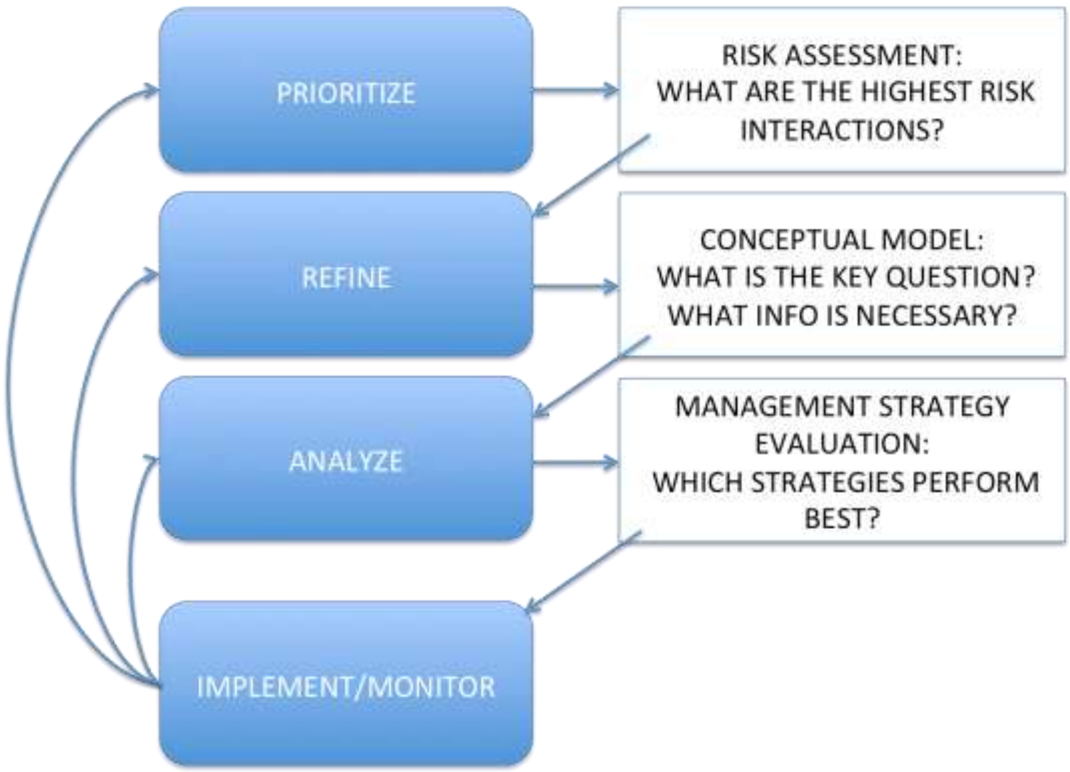

Figure 8: A potential framework for integrating interactions into management.

Step 1: Prioritize with risk assessment tools

There are so many possible interactions in a fishery ecosystem that one analysis or tool cannot effectively address them all, so **risk assessment** is proposed as the initial step to identify a subset of high priority interactions for the Council to address first. The Council's goals and objectives would shape the assessment by first identifying risks and impacts of concern. Risk assessment is a critical nexus of science and management because this is where scientific information feeds directly into management decision making, in particular in developing risk criteria and consequences. Risk assessment helps managers to decide where to focus limited resources by clarifying priorities. These methods could be used much more often for screening out interactions of lesser importance that may currently have equal or more resources devoted to them than higher risk interactions.

For example, the Council could conduct a comprehensive risk assessment relatively quickly that addresses all managed species and multiple risk categories. For example, the current status of each stock with respect to single species objectives could be included first, because preventing overfishing and keeping stocks above the overfished level are legally mandated objectives. Second, the Council could consider the level of stock assessment uncertainty and or data availability for each stock (addressing abundance estimates, etc., considered under section interactions and single species stock assessments above). Next, the level of fishery discards and how well/poorly they are accounted for in assessments could be considered. Food web considerations (whether species are key pray for other managed species, or predators that rely on other managed species), climate considerations (whether species productivity or distributions are expected to change), threats to habitat, and difficulties with allocation between fleets, fishery sectors, or regional jurisdictions could also be considered. While the Council would define these risk categories and others may be included, it is possible to visualize risks across species and categories (Figure 9). From here, the Council might consider species groups with the most high risks as priority candidates for further analysis of ecosystem interactions.

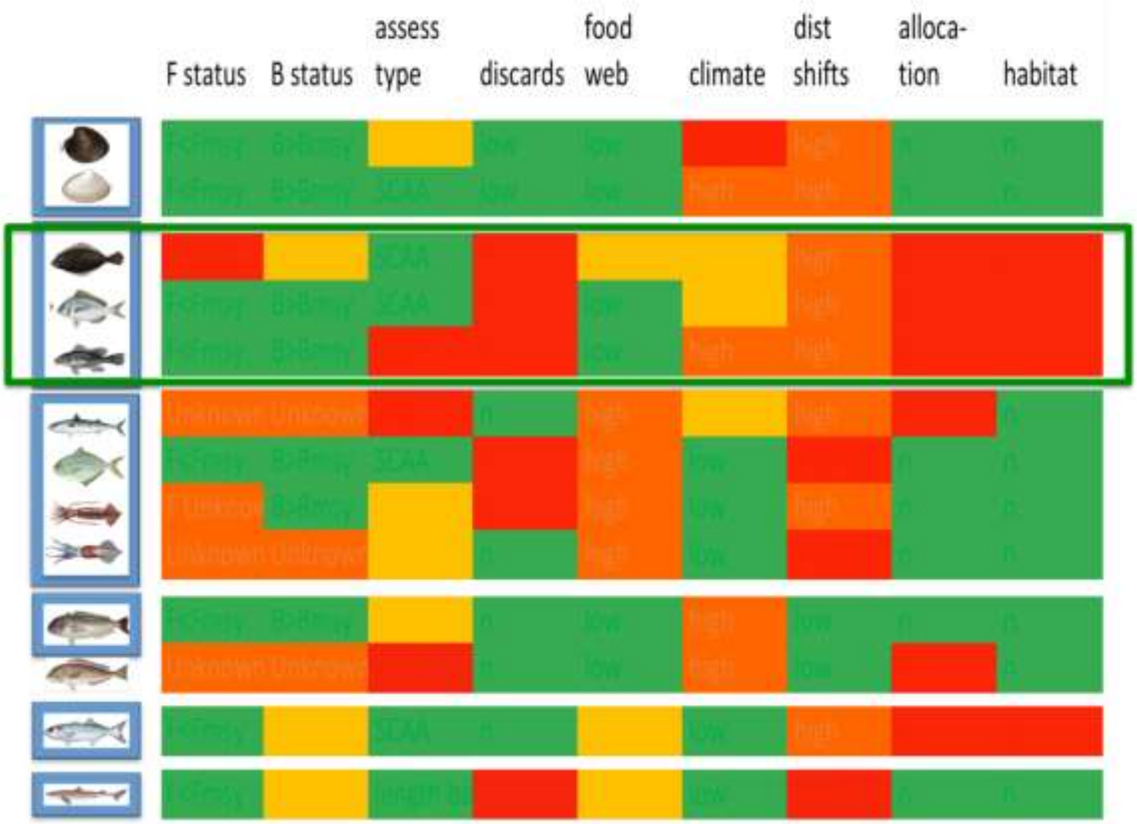

Figure 9: Example qualitative risk assessment across Council-managed species (left column) and mulitple risk categories (top row: see text for descriptions). Colors represent low (green), moderate (yellow), high (orange) and very high (red) risks within each category.

Step 2: Refine key management questions for highest risk interactions

What are the Council's primary questions regarding a given high priority interaction? What are the Council's objectives for integrating the interaction into management? As the Council refines the question with stakeholders, scientists can evaluate data availability and gaps, and identify analytical tools to address the question. While much data and many tools exist for the Mid-Atlantic region, adequate time for data acquisition and quality control and tool refinement should be allocated to ensure a tailor-made, appropriate analysis.

Basic conceptual models can be developed for the particular question during this process to ensure that key ecological, climate, habitat, fleet, social, and economic interactions are addressed. Conceptual models help organize analyses and information, and clarify interactions for all stakeholders to work from a common understanding. For example, a question centered on climate impacts to a particular species might start with a conceptual model of known climate and habitat interactions for that species, but build in any critical interactions with other species, fishing fleets, fishing communities, regional and global economic markets, etc., as necessary to address the questions and management objectives.

This step is critically important in the framework, because it adds a point in the process where interactions are systematically considered by using a multidisciplinary team with expertise appropriate to identify key interactions. For example, the existing Mid-Atlantic food web model is used to define key species interactions for each managed species, habitat expertise is needed to link habitat for species, physical oceanographic and climate expertise is needed to link key climate drivers to habitats, and the expertise of fishermen, economists and other social scientists and fisheries managers is needed to link fish with fisheries and objectives for human well-being (Figure 10). This conceptual model clearly connects climate considerations to management as well as habitat considerations of concern of the Council but outside Council jurisdiction (water quality in coastal estuaries).

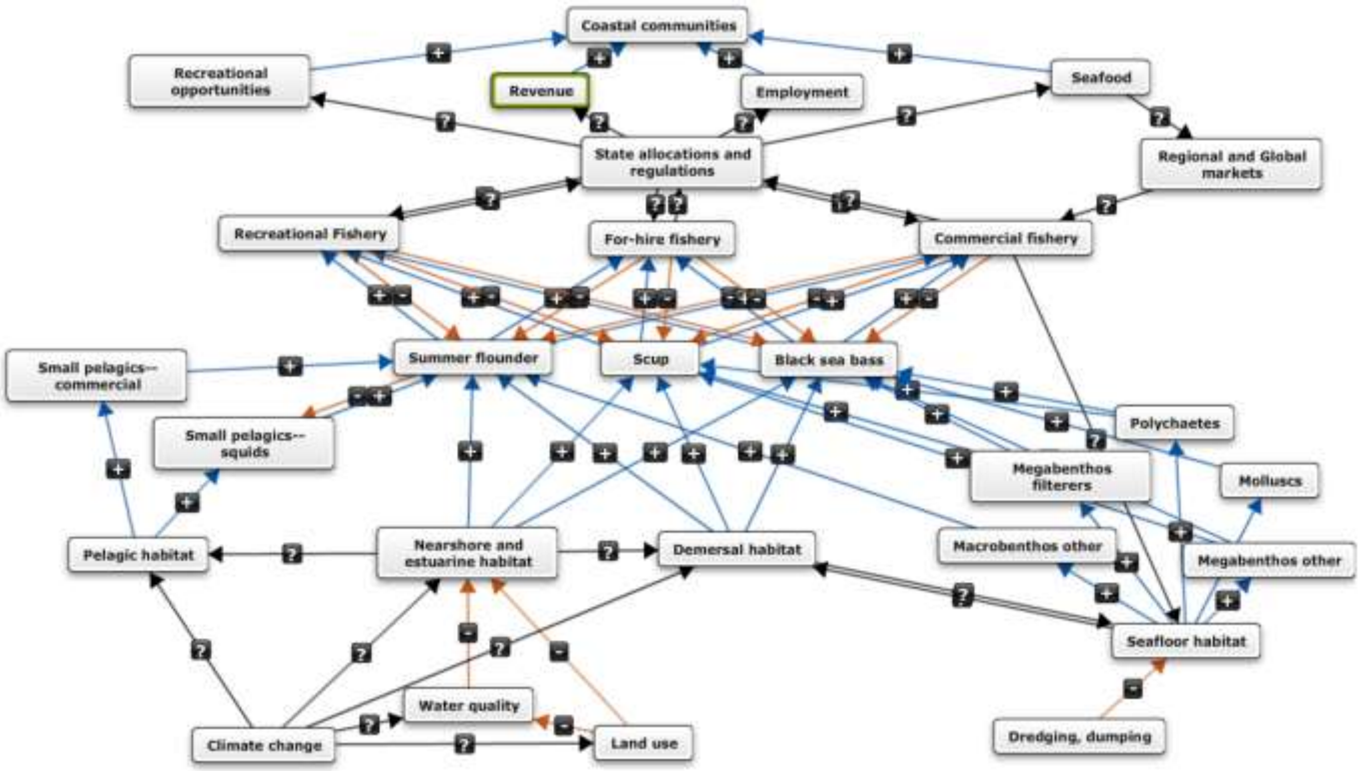

Figure 10: Conceptual model linking climate, habitat, species, fleet, and regulatory interactions for Council-managed species summer flounder, scup, and black sea bass. This is only an example for illustration and not a Council analysis.[17]

Step 3: Analyze management procedures with comprehensive management strategy evaluation

The Council's questions and objectives identified in Step 2, along with available data, tools, and management strategies feed into comprehensive MSE employing performance measures across biological, ecological, management, social, and economic outcomes. This iterative and stakeholder-driven process can evaluate the impacts of uncertainties in data collection systems, assessment methods, management decision processes, implementation of management measures, and other human activities as well as in the underlying climate, habitat, and ecology (Figure 11).

Some simulation models with capabilities to address species, habitat, climate, fleet, social, and economic interactions are available in the Mid-Atlantic region, although further development would be necessary for any particular MSE. Addressing questions with multiple simulation models and linking existing economic, single species, and ecosystem models expands analytical possibilities.

[17] Image created in online Mental Modeler Software (http://www.mentalmodeler.org/#download).

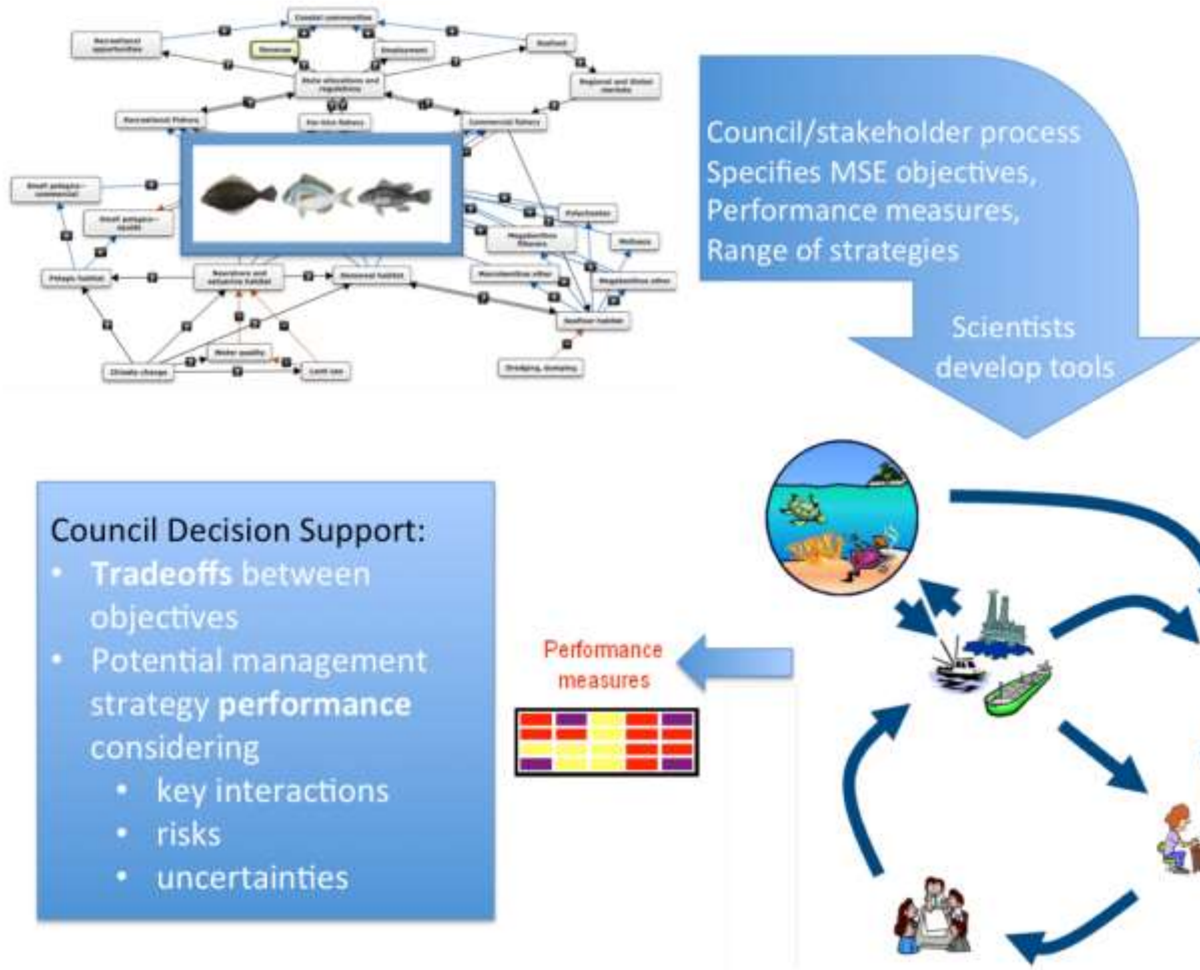

Figure 11: Linkages Between the conceptual model and the MSE process.[18]

Step 4: Implement, monitor, adapt, and iterate as needed

Management measures designed to address interaction between species, habitats, fleets, and climate forcing may require additional or different monitoring to determine if objectives are being met. Careful consideration of performance measures and monitoring systems to be used in real time needs to be part of this process. For example, an MSE requires the specification of performance measures to determine how well objectives are met; assuming that the performance measures represent actual data streams available to the Council these could also be used to monitor the actual performance of selected and implemented management measures. There is considerable potential to make better use of existing real time observing systems, in particular for climate and habitat interactions, as well as fishermen-based observation systems to evaluate management success. However, given that both climate and human uses of the ecosystem change over time, revisiting risk assessment, interactions conceptual models, and management strategies over time will be necessary.

[18] MSE representation adapted from figure by Beth Fulton at CSIRO; (http://www.cmar.csiro.au/research/mse/).

6. Conclusion

An ecosystem approach to fisheries management emphasizes a more integrated approach to habitat, sustainability, multi-species interactions, fleet dynamics and environmental drivers. As noted in the Council's 2006 document titled "Evolution Towards an Ecosystem Approach to Fisheries," the process to incorporating ecosystem factors into management needs to be "more evolutionary than revolutionary" (MAFMC 2006). Similarly here, the Council agreed to a systematic and strategic process to incorporate ecosystem considerations into the current management process and structure.

The goal of the EAFM approach is to enhance the Council's species-specific management programs with more ecosystem science, broader ecosystem considerations, and management policies that coordinate Council management across its FMPs and relevant ecosystems. The EAFM Guidance Document is a non-regulatory umbrella document and is intended to provide a framework for considering policy choices and trade-offs as they affect FMP species and the broader ecosystems. This document, and the guidance provided within, is intended to be adaptive and will continually be reviewed and revised as climate and ecosystem data, science and techniques continue to advance and help inform future Council considerations.

The Council took a deliberative, holistic, science based, and stakeholder driven process to help approach and develop their EAFM initiative, resulting in research and policy considerations for four major EAFM topics: 1) Forage Species Issues, 2) Climate Science and Fisheries, 3) Species Interactions, and 4) Ecosystem Level Habitat Considerations. These four ecosystem-related focus areas are addressed in this document in Sections 2-5. The bullets below summarize some of the key focus areas and recommendations that Council will work to address as it implements this guidance document.

- **Forage Species –** Maintain an adequate forage base to support feeding and production of economically valuable predator fishes. In reaching decisions on forage management, careful analysis of how tradeoffs affect yields, employment, profits, social well-being, and stock sizes of forage species, as well as other Council-managed species and unmanaged predators need to be considered. When considering forage fish policy and objectives, the Council should consider increasing the beneficial contribution of forage fish to the dynamics of both managed and unmanaged species, bolstering the resilience of the system, and enhancing the role forage fish play in the economy, and society more generally.

- **Habitat –** Recognize the essential role habitat plays in stock dynamics and the impacts climate change and increased climate variability will play in changing the physical and biological habitat dynamics. Identify and increase habitat focused research to support strengthened EFH designations, support Council habitat mandates, and understand the role of habitat in fishery productivity and ecosystem resilience. Effectively demonstrate and communicate the role of habitat and habitat science and the implications to fishery outcomes.

- **Climate Change and Variability –** Continued research and data collection related to the effect of climate on marine resources is key to supporting climate-ready fisheries management. As climate continues to affect fishery productivity and distribution, and as climate science initiatives continue to advance, the Council should consider and develop management approaches that are adaptive and flexible to respond quickly and appropriately to future changes.

- **Ecosystem Level Interactions –** The Council, including its science partners, will strive to increase the collection, utilization and consideration of ecosystem-level biological, social, and economic information into the management process. Continue to develop, refine and implement the structured EAFM framework in order to incorporate species, fleet, habitat, and climate interactions into management. Support the development and utilization of ecosystem-level assessments including risk assessment, conceptual model, and management strategy evaluation.

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