Draft Example Fishery Ecosystem Plan (eFEP)

for Georges Bank

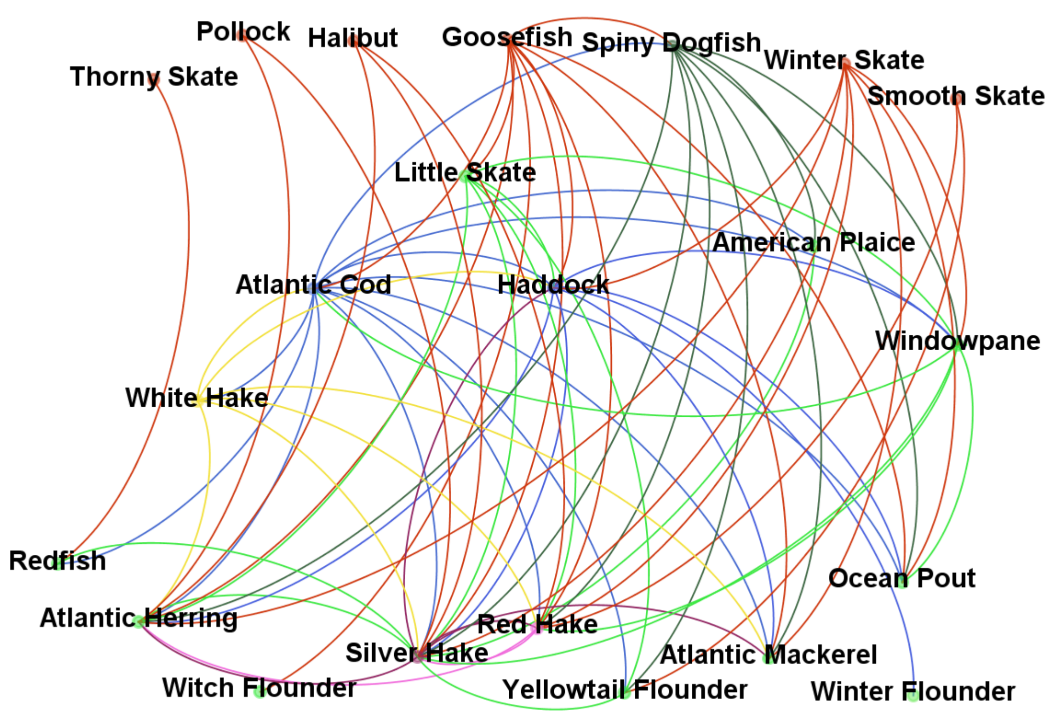
prepared by the

New England Fishery Management Council

and the

Ecosystem Based Fishery Management

Plan Development Team



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1.0 Executive Summary and Overview

The purpose of the eFEP document is to explain how a different type of management system could work and focus discussion on the possibilities. It is not intended to censure discussion of alternative approaches, but in fact is a starting point for further evaluation. Coupled with Management Strategy Evaluation (MSE), our intent is that it will identify viable management approaches to achieve a broad range goals and objectives that will become an approved Fishery Ecosystem Plan, replacing existing plans that govern fishing on Georges Bank. If successful, similar FEPs may eventually be developed and implemented elsewhere by the NEFMC.

The eFEP proposes a framework to manage fisheries in a way that is more adaptive to changes in the ecosystem production, more flexible for fishermen to make better choices about where and how to fish, and sets limits on catch that are more consistent with achieving a broad range of objectives and improved ecosystem services.

What is different about a Fishery Ecosystem Plan (FEP) is that

- It has the potential to consider a broader range of goals, objectives, and improvements of ecosystem services than is normally considered in traditional fishery management plans (FMP).

- Sets a limit on total ecosystem catches that consider system-wide primary productivity and net import of energy from neighboring ecosystem production units.

- Harvest control rules for stock complexes (that limit the amount of catch) take into account interactions amongst predators and prey, given their stock size. Harvest control rules of stock complexes that have common trophic and biological characteristics are thought to be more stable and robust than those associated with singles species control rules designed to achieve a static target biomass.

- It may be more adaptive and flexible, allowing vessels to catch and land a suite of species in a stock complex. Thus, it has the potential to reduce inefficiencies, such as catching fish that cannot be retained because of permit or regulatory limitations. We call these ‘technical interactions’.

- Because the FEP accounts for the biological interactions among related stock in an EPU, the productivity of an individual stock is understood to vary with changes in relative abundance of both predators and prey. As a result, maximum sustainable yield (MSY) is no longer thought of as a static value.

Why did we choose Georges Bank?

A FEP is spatially oriented to manage fishing in a distinct area defined by biological and oceanographic characteristics. Some stocks may occur entirely or primarily within the boundaries of this distinct area, or Ecosystem Production Unit (EPU) or may overlap with neighboring EPUs. Georges Bank was chosen because a considerable amount of ecological science and modelling has focused on this distinct area.

Fishery Ecosystem Plan issues discussed in this document

Scientists, managers, fishermen and stakeholders have long realized the problems associated with single species management, where harvest control rules are specified for a stock often ignoring the relative abundance of predators and prey. Often the focus of management (i.e. goals and objectives) is to achieve Maximum Sustainable Yield as an attainable goal for that stock and simultaneously for all other stocks in the region. Thus management may not be optimizing the benefits to be achieved from the ecosystem or recognize its practical limits on energy production. Benefits other than from fishing or from catches of higher abundance of large fish as well as for apex predators, marine mammals, and seabirds or often not considered directly. Sometimes these benefits are recognized as indirect outcomes, rather than an integral part of fishery management policy.

Permitting and access to the fishery are often fragmented, based on historic participation instead of current circumstances. For example, some vessels that fish for skates or monkfish do not have a permit to fish for and retain groundfish or summer flounder, or vice versa. As a result, many biological and technical interactions are ignored or are problematic, creating fewer opportunities and higher costs for fishermen.

A Fishery Ecosystem Plan can address these problematic issues in several ways. Integrated ecosystem fishery management can offer:

- A broader consideration of benefits that arise from the ecosystem, recognizing the various tradeoffs that exist and the values of different types of stakeholders.
- A system control that recognizes the practical limits on energy production, starting with levels and trends in primary productivity
- Harvest control rules and assessments that account for the biological interactions among stocks of fish and marine species.
- Catch allocations and permitting that are consistent with and allow for flexibility to catch and land fish species that encounter the types of fishing gear in use.
- The opportunity and potential to resolve existing regulatory inconsistencies, thereby reducing compliance and enforcement costs.

This document describes a management approach, or operational framework, to conduct an evaluation of potential ecosystem management strategies using one or more operating models. The purpose of the document is to support evaluation of management procedures through Management Strategy Evaluation, described in Section 8.0. Nothing in this document is set in stone or implies that it is the only way to implement ecosystem management, but lays out a high-level framework that we believe is a possible way forward. The final result may be a Fishery Ecosystem Plan or Ecosystem Approach that is different than the one described here.

This document also describes the concept of ecosystem-based fishery management (EBFM) applied to a Georges Bank Ecosystem Production Unit (EPU). It defines the scope of what can be managed under a FEP, including the spatial extent, the species and stocks that can be managed, and the management jurisdiction of stocks and fisheries included in the FEP. The document gives examples of management procedures (i.e. a framework of catch limits for stock complexes, floors to prevent depletion of stocks, and allocations to fishery functional groups defined by fisheries that have specific characteristics and that catch co-occurring fish) that may be used to manage the EPU, as well as the scope of technical measures that can be utilized. The document also describes some operating models that can be used to evaluate candidate management procedures, as well as the model inputs (e.g. growth, survival, recruitment, trophic interactions, movement, etc.) that describe the potential states of the ecosystem.

For purposes of further analysis and discussion, this document lays out a description of an analytical framework for a Fishery Ecosystem Plan for the Georges Bank Ecosystem Production Unit as a proof of concept. It provides core elements of a Fishery Ecosystem Plan to set the stage for full development of an FEP. This framework will require a different view, interpretation, and application of National Standard 1 than is traditionally taken. We do note however that there are many examples of managing stock complexes, but what is different is that we account for the biological interactions and system productivity to define MSY. We believe that the framework described here can provide sufficient protections to be consistent with National Standard 1 and do a better job at producing optimum yield.

The approach is centered on developing management strategies for providing multispecies catch advice and explicitly testing those strategies on a simulated Georges Bank Ecosystem through a process of Management Strategy Evaluation (MSE), which is the next step in developing viable EBFM strategies. MSE comprises one or more operating models, candidate assessment methods, and potential management procedures for the system. Given a set of objectives defined by the NEFMC and interested parties and/or advisors, MSE can be used to compare the probable success of alternative management procedures.

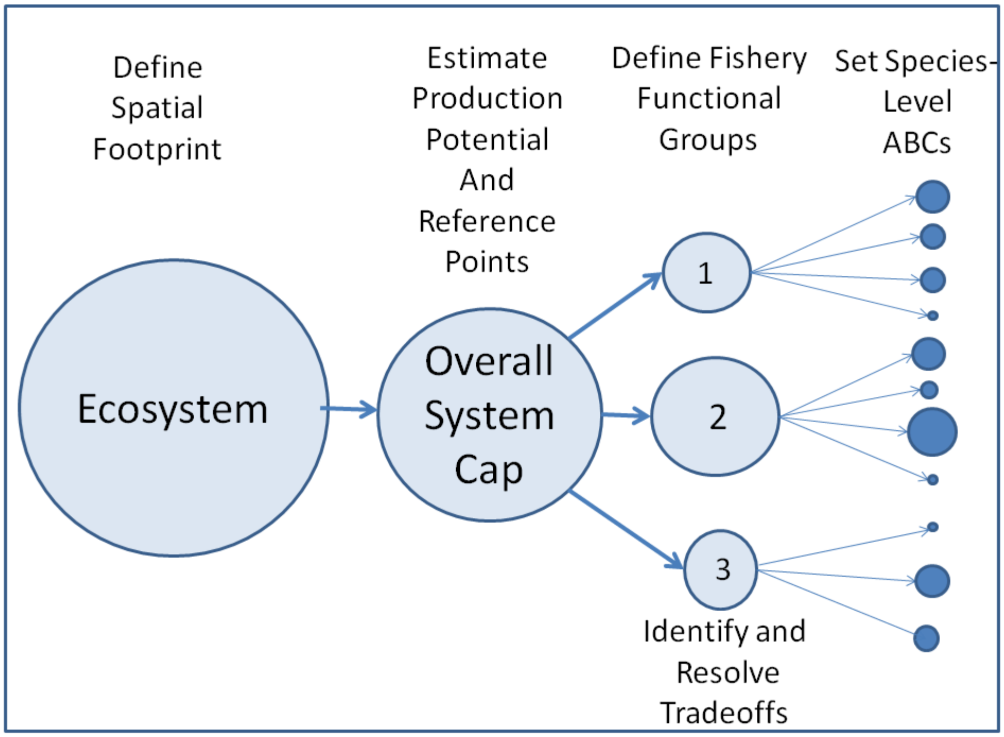
This document provides details about the systems, models, management process, and context/rationale for the development of an ecosystem plan. The document is intended to be a starting point for further discussion and performance analysis. It sets the stage for the process to be followed in the development of the FEP based on the principles noted above. To prepare for the start of this process, the Council has assembled existing information on the Georges-Bank Fishery Ecosystem and has worked with one candidate operating model to conduct exploratory analyses. Changes and adjustments to the operating models and how catch advice under the FEP are generated is to be expected based on essential stakeholder engagement meetings that will start this process.

The overall approach is to assign species to Species Complexes using a combination of feeding guilds, technical interactions with fisheries and other ecosystem components, as well as biological characteristics. The strategy would employ an overall Ecosystem Production Unit (EPU) catch cap based on the estimated energetics of the system and observed primary productivity (Section 7.1). Catch limits by Species Complex would be allocated to Fishery Functional Groups, but in aggregate should not exceed the EPU catch cap that would define overfishing (Section 7.2). Biomass 'floors' for stocks and stock complexes would be established to protect species from becoming unacceptably overfished or depleted (Section 7.2). These floors could be developed using survey information and could be based on a low percent of maximum stock size, considering the effect on risk and economic return.

The key elements of the approach described in this document include the objective specification of the spatial domain [Ecological Production Unit (EPU)] to be managed, the identification of Fishery Species Complexes defined by trophic interactions, with Fishery Functional Groups defined by co-occurrence in fishing gear within the EPU, and the critical role of management strategy evaluation in evaluating management options under consideration. It further requires the identification of Ecosystem Reference Points establishing limits and targets for management and methods for determining catch levels in an ecosystem context (See figure below)).

Consideration of energy flow and constraints on overall production in the system provide the foundation for the approach. Constraints related to patterns of energy flow and utilization and biological interactions within and between Fishery Species Complexes contributes to greater stability at higher levels of ecological organization.

Elements of the proposed hierarchical process for specifying Acceptable Biological Catch levels for species within defined Fishery Species Complexes.



Seventy-four species are commonly found in the Georges Bank EPU and have been assigned to Species Complexes (Section 4.3 and Table 8). In many cases, a catchability-adjusted swept-area biomass was estimated, but many species are also not well selected and sampled by trawl survey gear, but are trophically related.

This document describes three operating models, or ecosystem simulations, that have been applied to Georges Bank species (Section 8.0). The Hydra model is well developed and has been parameterized to include 10 most common species. The Atlantis and Ecosym/Ecopath (EwE) models are also described. They are more comprehensive and complex, but can potentially provide results for a broader range of objectives.

There are also several sections (Section 7.0, 8.0, and 9.1) that focus on potential strategies for using the operational models and applying viable management procedures in this framework. They include a description of performance metrics and analysis including risk assessment, management strategy evaluation, and other related Fishery Ecosystem Plan (FEP) components.

Finally, Section 10.0 includes a summary and description of the Georges Bank EPU. In total, this document describes an operating framework and potential management strategies, but it is not the Fishery Ecosystem Plan (FEP) itself. The FEP would include additional features like strategic goals and objectives, as well as some broad management approaches.

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2.4 Acronyms used in this document

ACL	Annual catch limit, associated with MSY but takes uncertainty and risk into account; may pertain to a stock or stock complex.
ASMFC	Atlantic States Marine Fisheries Commission

EPU	An area that circumscribes a region with similar ecological characteristics
FFG	Fishery Functional Group – an allocation of a stock complex to a specific fishery or mode of fishing, aka a métier.
HMS	Highly Migratory Species Management Division, NOAA Fisheries
MAFMC	Mid-Atlantic Fishery Management Council
MSY	Maximum sustainable yield
MU	A management unit, which refers to a sub-area of an EPU where special permitting or regulations may apply
NEFMC	New England Fishery Management Council
NEFSC	Northeast Fisheries Science Center
SC	Stock complex, a group of stocks or substocks with similar life-history and trophic characteristics which may be grouped together to set ACLs

3.0 Introduction

The need to adopt a more holistic view of human impacts on and benefits derived from the marine environment is now widely recognized. Global initiatives are now underway to implement integrated management strategies for ocean resource management recognizing the complexity of these systems, the role of humans as part of the ecosystem, and attempts to formulate strategies for sustainable use of natural resources in response to the cumulative effects of multiple stressors in the marine environment. Sectoral management issues, including fisheries management, fall under the broad remit of Ecosystem-Based Management. NOAA Fisheries has recently issued a policy statement defining Ecosystem-Based Fisheries Management (EBFM) as a

> '*…systematic approach to fisheries management in a geographically specified area that contributes to the resilience and sustainability of the ecosystem; recognizes the physical, biological, economic, and social interactions among the affected fishery-related components of the ecosystem, including humans; and seeks to optimize benefits among a diverse set of societal goals'*

and an ecosystem is defined as:

> *'a geographically specified system of fishery resources, the persons that participate in that system, the environment, and the environmental processes that control that ecosystem's dynamics. (c.f. Murawski and Matlock, 2006, NMFS-F/SPO-74). Fishermen and fishing communities are therefore understood to be included in the definition'.*

The above statement emphasizes that EBFM is inherently place-based, identifies the need to consider the interaction among system components in management and highlights the ways in which human communities both influence and are affected by changes in the ecosystem. Because the properties of an ecosystem are different from those of its parts, EBFM will necessarily differ from traditional single species approaches while maintaining some elements of more traditional management structures and tactical tools.

Consideration of ecosystem-level approaches to fishery management has a long history in the Northeast US. The fundamental difficulties inherent in managing multispecies fisheries in the region were identified by McHugh (1959) who called for management *'en masse'*, effectively advocating management of species assemblages in the aggregate rather than of individual stocks. Edwards (1968) developed estimates of total fish biomass and productivity for the Northeast U.S. continental shelf and Brown and Brennan (1972) and Brown et al. (1976) subsequently developed estimates of maximum sustainable yield for the fish species complex of the northeast shelf as a whole. Implementation of the 'Two-Tier' quota management system in this area by the International Commission for Northwest Atlantic Fisheries in 1973, incorporating an upper constraint (second tier) on total removals (reflecting overall levels of system productivity) and individual species-level constraints (first tier) followed as a direct result (Edwards 1975; Hennemuth and Rockwell 1987). Current discussion of the adoption of holistic approaches to fisheries management on the Northeast continental shelf is therefore firmly grounded in historical precedent.

The Scientific and Statistical Committee (SSC) of the New England Fisheries Management Council (NEFMC) developed a strategy document considering issues and potential pathways for implementing EBFM (NEFMC 2010) in the Northeast US. The SSC noted that a transition to EBFM offered opportunities for:

- The potential for simplification of management structures with associated cost savings in ultimately moving from a large number of species/stock-based management plans to a smaller number of integrated plans for ecological units defined by location.
- More realistic consideration of the effects of both fishery interactions (e.g. bycatch in different fleet sectors) and biological interactions (e.g. consideration of predator-prey interactions) within ecological units, including consideration of effects on biodiversity.
- Direct consideration of environmental/climate-related change, its effect on productivity and biological reference points.
- Consideration of the ecosystem constraints on simultaneous rebuilding of stocks to long-term target levels and evaluation of whether or not stock – specific recovery plans are compatible.
- More effective coordination among management actions taken for fishery management and protected resources (i.e., species protected under the Endangered Species Act or Marine Mammal Protection Act).

Currently the New England Fishery Management Council administers nine fishery management plans. Of these, six are single-species plans and the remaining three include consideration of multiple species bundled within overarching management plans (although interactions among the species are not currently directly considered in these plans). The Northeast Multispecies Groundfish plan covers 13 species (and a total of 20 stocks) while the Small Mesh Fishery Management Plan includes three hake species. The Skate Fishery Management Plan covers seven species. Adopting a spatial management strategy would substantially consolidate the number of individual fishery management plans administered by the council and would facilitate consideration of important interactions among species and fisheries now under separate management plans. To the extent that factors such as biological and technical interactions and climate effects are important but not directly taken into account in current management, such as whether simultaneous rebuilding of stocks and the choice of long term target levels, will remain in question. Adoption of EBFM would allow these issues to be addressed within an integrated framework.

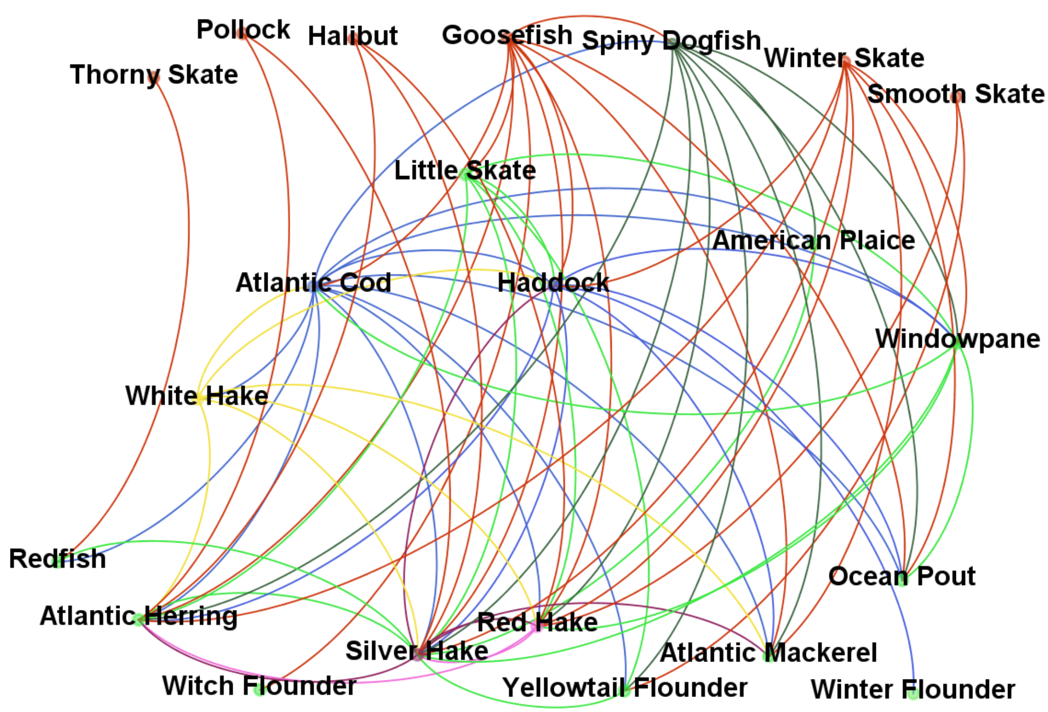
The unique challenges associated with managing mixed- species fisheries have been recognized by the NEFMC from its inception. To address these concerns and to formulate management strategies directed specifically at the mixed- species problem, the Northeast Fishery Management Task force was convened in 1979. The Task Force explicitly identified the limitations of attempting to apply single-species management strategies to stock complexes comprising interacting species:

- "*In view of the dynamic interactions in nature, a single-species approach to management is inadequate, particularly for multispecies fisheries, or fisheries where the by-catch is significant.*

- *To avoid the deficiencies of a single-species approach, management might address itself to the productivity and harvest potential of an entire ecosystem, since the ecosystem in the long run has greater stability than any of its components, However, to be practical, management must recognize the social fact that some species are more desirable than others, and in some measure direct the fisheries to certain species. This suggests a multispecies scheme of management: individual species, groups of species, or particular fisheries (defined by area or gear) would be regulated to control the relative balance of the species mix" (Hennemuth et al. (1980)*

These difficulties have played out in the course of groundfish management in the Northeast over the last several decades, leading to a seemingly intractable problem (Apollonio and Dykstra 2008). Of the stocks managed by NEFMC, fifteen are currently classified as being overfished. Of these, eleven are managed under the Northeast Multispecies Groundfish Management Plan. The dominance of complex mixed-species fisheries involving stocks connected by both biological interactions (notably predation and competition) and technical interactions resulting in by-catch of targeted and untargeted species, plays a central role in the difficulties in establishing effective management strategies in this region (Apollonio and Dykstra 2008). The nature of the problem is highlighted in Figure 1.1 in which NEFMC managed species connected by predator prey interactions are shown.

Figure 1. NEFMC managed species connected by predator-prey interactions based on Northeast Fisheries Science Center diet composition studies (see Smith and Link 2010 for a summary of methods and results). Connections between predators (red node) and their prey (green nodes) are shown for species pairs in which any predation interactions were recorded.



Potential competitive and by-catch interactions further contribute to the highly inter-connected nature of this fishery system and to the inherent difficulties in managing the fish assemblages found in New England mixed species fisheries using traditional single species approaches. A principal motivation for exploring alternative management strategies based on ecosystem principles, and multispecies approaches in particular is rooted in the complexity of these mixed-species fisheries.

The Council has tasked its EBFM Plan Development Team with developing

> *"An example of a fishery ecosystem plan that is based on fundamental properties of the ecosystem (e.g., energy flow and predator/prey interactions) as well as being realistic enough and with enough specification such that it could be implemented. The example should not be unduly constrained by current perceptions about legal restrictions or policies"*

In this document, we attempt to address this mandate. We explore options for an evolutionary development of the existing multispecies and single species management plans to encompass explicit consideration of interspecific interactions, by-catch, and environmental/climate change. We build on the existing structures and formalize the adoption of a systems approach to management of the resources under the jurisdiction of the council.

For purposes of further analysis and discussion, this document lays out a description of an operational framework for a Fishery Ecosystem Plan for the Georges Bank Ecosystem Production Unit as a proof of concept. It is intended to lay out the analytical underpinnings of a Fishery Ecosystem Plan for this region. The approach is centered on developing management strategies for providing multispecies catch advice and explicitly testing those strategies on a simulated Georges Bank Ecosystem through a process of Management Strategy Evaluation (MSE). MSE comprises one or more operating models, candidate assessment methods, and potential management procedures for the system. Given a set of objectives defined by the NEFMC and interested parties and/or advisors, MSE can be used to compare the probable success of alternative management procedures. This document provides details about the systems, models, management process, and context/rationale for the development of an ecosystem plan. The document is intended to be a starting point for further discussion and performance analysis. It is intended to set the stage for the process to be followed in the development of the FEP based on the principles noted above. To prepare for the start of this process, the PDT has assembled existing information on the Georges-Bank Fishery Ecosystem and has worked with one candidate operating model to conduct exploratory analyses. Changes and adjustments to the operating model and how catch advice under the FEP are generated is to be expected based on stakeholder engagement meetings that will start this process.

The core components for the operational framework are a set of strategic objectives defined by managers and interested parties, coupled with a set of ecosystem and multispecies assessment models that provide tactical advice under a hierarchical management approach. A linked management strategy includes the process for setting and adjusting catch limits based on the assessment model outputs that are intended to meet the ecosystem objectives. To test potential management procedures prior to implementing them in reality, MSE is proposed. The MSE contains a feedback loop from the management actions through to fishing a simulated Georges Bank ecosystem (such as occurs in reality). The simulated Georges Bank ecosystem is called the operating model. The MSE, thus, provides a test bed for adjusting the parameters of the management tools to quantify tradeoffs among the objectives with the goal of determining which management procedures and tools provide robust outcomes across uncertainty and objectives.

4.0 Goals and objectives

The following list of goals and objectives were adopted by the NEFMC for use in this eFEP, as a starting point for focusing debate. The Council expects that these goals and objectives will be revised or given relative weights during a Management Strategy Evaluation.

4.1 Goals – measurable or desirable outcomes

4.1.1 Overarching Goal

To protect the ecological integrity of US marine resources as a sustainable source of wealth and well-being for current and future generations (Goal A)

4.1.2 Strategic Goals (Derived from Magnuson definition of OY as in Risk Policy Document):

1. Optimize Food Provision through targeted fishing and fishing for species for bait
2. Optimize Employment
3. Optimize Recreational Opportunity
4. Optimize Intrinsic (Existence) values
5. Optimize Profitability
6. Promote stability in both the biological and social systems

4.1.3 Objectives - General description of how the FEP is designed to achieve goals

4.1.3.1 Strategic Objectives

1. Maintain/restore functional production levels (ecosystem, community scale emphasis)
2. Maintain/restore functional biomass levels (community/species scale emphasis)
3. Maintain/restore functional trophic structure
4. Maintain/restore functional habitat

4.1.3.2 Operational Objectives (SMART: Specific, Measurable, Achievable, Relevant, Time-bound)

1. Ecosystem and community/aggregate fishing mortality and or total catch is below established dynamic threshold (Strategic Objective 1)
   a. Phrased as probability according to risk policy
   b. Specified for each spatial scale and time unit
   c. Dynamic to account for environmental/climate shifts
   d. "GB EPU total catch has less than 40% probability of exceeding the total catch limit between 2016-2018"

2. Fishing-related mortality for threatened/endangered/protected species is minimized (could establish caps if desired) (Strategic Objective 2)

3. Managed and protected species biomass is above established minimum threshold (Strategic Objectives 1, 2 and 3)
   a. Phrased as probability according to risk policy
   b. Specified for each spatial scale and time unit
   c. Dynamic to account for environmental/climate shifts
   d. "GB haddock biomass has less than 40% probability of dropping below minimum B threshold between 2016-2018"

4. Maintain ecosystem structure within historical variation, recognizing inherent dynamic properties of the system; Ecosystem structure includes size structure, trophic structure, and Species Complex structure. (Strategic Objective 3)

   a. Maintain size structure within acceptable limits; e.g. *The large fish indicator within defined limits

   b. Maintain trophic structure within acceptable limits; e.g.
      i. *Marine trophic index of the community (MTI) within defined limits
      ii. *Mean trophic level of the community within defined limits
      iii. *Mean trophic level of the modelled community within defined limits

   c. Maintain Species Complex structure within acceptable limits; e.g. * species complex biomass across ecosystem components within defined limits

5. Maintain habitat productivity and diversity (Strategic Objective 4)

6. Habitat structure and function are maintained for exploited species

7. Minimize the risk of permanent (>20 years) impacts; e.g.
   a. Corals and sponges
   b. Other vulnerable biogenic habitats
   c. Coastal habitats vulnerable to Aquatic Invasive Species (AIS)
   d. Vulnerable physical habitats (e.g. relict glacial gravel banks)

5.0 Overview of FEP framework

In the following sections, one potential strategy is described for defining and implementing a holistic approach to EBFM for the Northeast continental shelf. Guiding principles in approaching this problem include:

a. the desirability of striving for simplicity,
b. the importance of building on advances made in current management and analysis, particularly in establishing safeguards for exploited species,
c. the value of capitalizing on emergent ecosystem properties
d. the need to identify transparent adaptive management strategies, and
e. recognition of the need to confront the issue of tradeoffs among potentially competing objectives.

Building on these principles, we address the need to:

- Define clear objectives for the management program
- Identify spatial management units
- Determine constraints on system productivity conditioned on environmental states
- Select a ceiling for sustainable ecosystem exploitation rate
- Devise an allocation strategy for species-specific catches
- Decide on the mix of management tools to be employed to achieve objectives
- Apply formal strategies of decision theory to confront tradeoffs.

This Fishery Ecosystem Plan (FEP) framework will consider the management of living marine resources within ecological production units in an integrated, systemic fashion, providing a holistic perspective but at the same time providing flexibility for addressing societal objectives within biodiversity constraints provided by overfishing and overfished criteria central to legislation. A key element of the plan is to directly confront the difficulties that emerge in non-selective mixed species fisheries, making management of the multispecies groundfish fishery particularly problematic. The approach outlined below further seeks to simplify management by taking advantage of emergent properties of the fishery system resulting in greater stability and resilience of the whole relative to the parts. Central to the overall approach is the need to consider the fishery as an integrated social-ecological system and not a collection of parts. The ecological considerations underlying the approach focus on constraints related to patterns of energy flow and utilization. Emergent properties at higher levels of ecological organization (species complexes, communities) that provide a focal point in this strategy are suggested to be a direct result of energetic constraints in the system.

6.0 Scope

The objective identification of spatial management units is a critical pre-requisite for the development of Ecosystem-based Fishery Management. In this section, we describe previous designations of spatial boundaries of Ecological Production Units (EPUs) on the Northeast U.S. Continental Shelf based on physiography, hydrography, and production at the base of the food web. We then provide information on the spatial distribution of a number of ecosystem components including marine mammals, sea turtle, seabirds, fish, and benthic invertebrates in relation to the EPUs. To explore how fishers see the ecosystem as reflected in fishing patterns, we map fishing activities defined in relation to the species composition of the catch in relation to the EPU boundaries.

6.1 Ecological Production Units

Geographically-defined ecological units have previously been proposed for the Northeast Continental Shelf from Cape Hatteras to the Gulf of Maine. The region in its entirety has been designated as a Large Marine Ecosystem (LME) on the basis of bathymetry, productivity, population structure and fishery characteristics (Sherman and Alexander 1986). Longhurst (1998) identified three subdivisions of his Northwest Atlantic Shelves Province falling within the Northeast Shelf (NES) LME: *(1) Gulf of Maine and Bay of Fundy, (2) Shelf from Georges Bank to Long Island, and (3) Middle Atlantic Bight*. Subareas of the NES LME have also previously been defined for the Northeast Shelf for fishery assessment purposes. Clark and Brown (1977) considered a four-unit subdivision of the NES LME within U.S. waters including *(1) Gulf of Maine (2) Georges Bank (3) Southern New England and (4) Middle Atlantic* regions. Very few stock assessments include as many as four stock units and the vast majority (over 80%) comprise a single stock unit representing the observed area of occurrence of each stock species within the Northeast Shelf region. To meet a broader set of management mandates, the Northeast Regional Action Plan (Higgens et al. 1985) delineated six Water Management Units within the Northeastern United States: (1) *Coastal Gulf of Maine*, (2) *Gulf of Maine*, (3) *Georges Bank west to Block Channel*, (4) *Coastal Middle Atlantic, (5) Middle Atlantic Shelf* and (6) *Offshelf*.

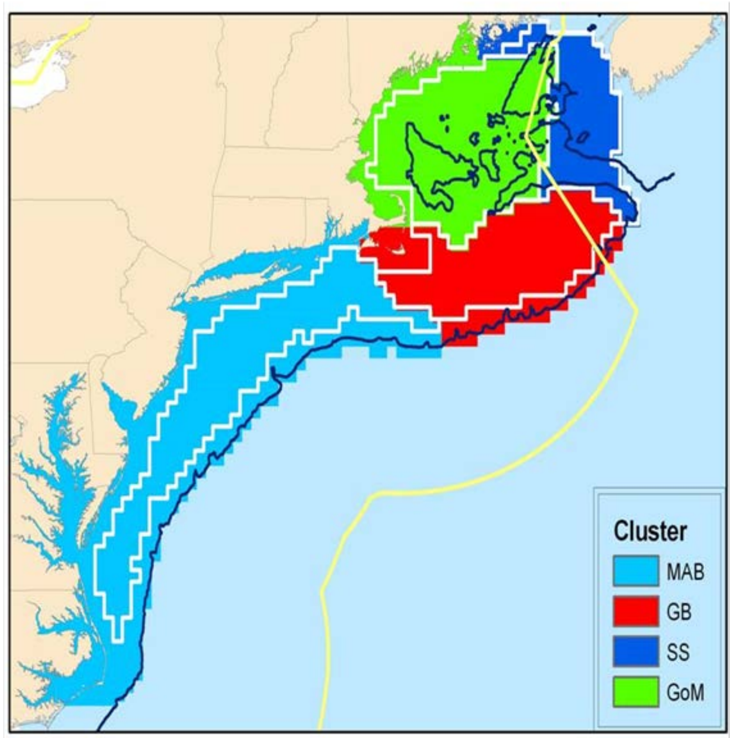
Fogarty et al. (2012; in prep.) defined Ecological Production Units on the Northeast U.S. continental shelf based on: (1) bathymetry, (2) bottom sediments, (3) satellite-derived estimates of sea surface temperature and annual temperature span , (4) ship-board estimates of surface and bottom temperature and salinity in spring and autumn based on Northeast Fisheries Science Center research vessel surveys, (5) satellite-derived estimates of chlorophyll concentration and primary production and (6) satellite-derived estimates of sea surface temperature and chlorophyll gradients to identify frontal zone positions. Seven major production units were identified based on a cluster analysis of the physiographic, oceanographic and basal trophic level variables. The production units included: (1) Eastern Gulf of Maine- Scotian Shelf, (2) Western-Central Gulf of Maine (3) Inshore Gulf of Maine, (4) Georges Bank-Nantucket Shoals (5) Intermediate Mid-Atlantic Bight (6) Inshore Mid-Atlantic Bight and (7) Continental Slope (Cape Hatteras to Georges Bank). These spatial units are considered to be open and interconnected, reflecting oceanographic exchange and species movement and migratory pathways. These boundaries are remarkably consistent with the sub-regions of the shelf proposed by Higgens et al. (1985) based on qualitative measures and expert opinion in the development of their ocean management areas.

Fogarty et al. (2012; in prep) proposed further consolidation of some ecological subareas to reflect movement patterns of exploited species from both the shelf-break region and the immediate nearshore regions to the adjacent shelf areas. The shelf-break regions are considered special zones associated with the adjacent shelf regions. The option for special management considerations to be implemented in both nearshore and shelfbreak areas to reflect the distribution of ecologically sensitive species, areas of high biomass and species richness, and/or the confluence of multiple human use patterns in nearshore regions is also considered. Following this approach, four major ecological zones (Figure 2) including:

1. the Western-Central Gulf of Maine,
2. the Eastern Gulf of Maine-Scotian Shelf,
3. Georges Bank-Nantucket Shoals, and
4. the Mid-Atlantic Bight

For the purposes of this representation, we have included estuaries and embayments with the nearshore regions but note that it may be desirable to identify these areas separately in the overall spatial structure.

Figure 2. Proposed ecological subunits of the Northeast Continental Shelf including (1) Western-Central Gulf of Maine (GoM) (2) Eastern Gulf of Maine-Scotian Shelf (SS), (3) Georges Bank-Nantucket Shoals (GB) and (4) Middle-Atlantic Bight (MAB). White lines indicate boundaries between areas, including the designation of special areas at the edge of the continental shelf and in the immediate nearshore areas of the Middle-Atlantic Bight and the Gulf of Maine.



6.2 Fishing Patterns in Relation to the Georges Bank Ecological Production Unit

Lucey and Fogarty (2010) defined operational fisheries for fishers operating out of New England ports on the basis of species catch compositions in space and time in relation to Ecological Production Unit boundaries. Analyses were conducted separately for six gear types (otter trawl; dredges, pots; longlines, gillnets, and seines. Each gear category was further divided by vessel size. Small vessels were designated as those with a gross registered tonnage less than or equal to 150 tons, while large vessels were designated as those with a gross registered tonnage of greater than 150 tons. Murawski et al. (1983) had earlier delineated a total of 29 operational fisheries for the otter trawl fleet of New England which were then consolidated into 9 major operational trawl fisheries. Lucey and Fogarty (2010) defined a total of 36 operational fisheries for vessels originating in New England ports and operating on the Northeast US Continental Shelf. Of these, ten were found to have a substantial presence on Georges Bank (although none were limited to the confines of the Georges Bank EPU. Three otter trawl fisheries operating on Georges Bank from New England ports differed principally with respect to the relative mix of groundfish species targeted and their spatial location on the bank (Otter trawl operational fisheries 1,5, and 8; see Table 1 and Figure 3). One of these otter trawl fisheries also landed lobster (otter trawl fishery 1) and trawl fishery 8 also landed short fin squid (*Illex*). Of three identifiable longline operational fisheries, each targeted cod and haddock in different proportions while one (longline operational fishery 2) also landed pollock and spiny dogfish (Table 1). The spatial footprint of these three longline fisheries is shown in Figure 4. Pot fisheries on Georges Bank focused on lobster (pot fishery 1; Figure 5), lobster and Jonah Crab (pot fishery 2), and red crab (pot fishery 3). The latter operated exclusively on the shelf break (Figure 5). Finally, the sea scallop dredge fishery was broadly distributed throughout the Mid-Atlantic region and onto Georges Bank (Figure 6).

Table 1. Proportional species contribution to the identification of operational otter trawl, longline, pot and dredge fisheries encompassing Georges Bank. Black boxes represent a large contribution (>20%), grey boxes represent a medium contribution (~5-20%), light grey boxes represent a medium contribution (~1-5%).

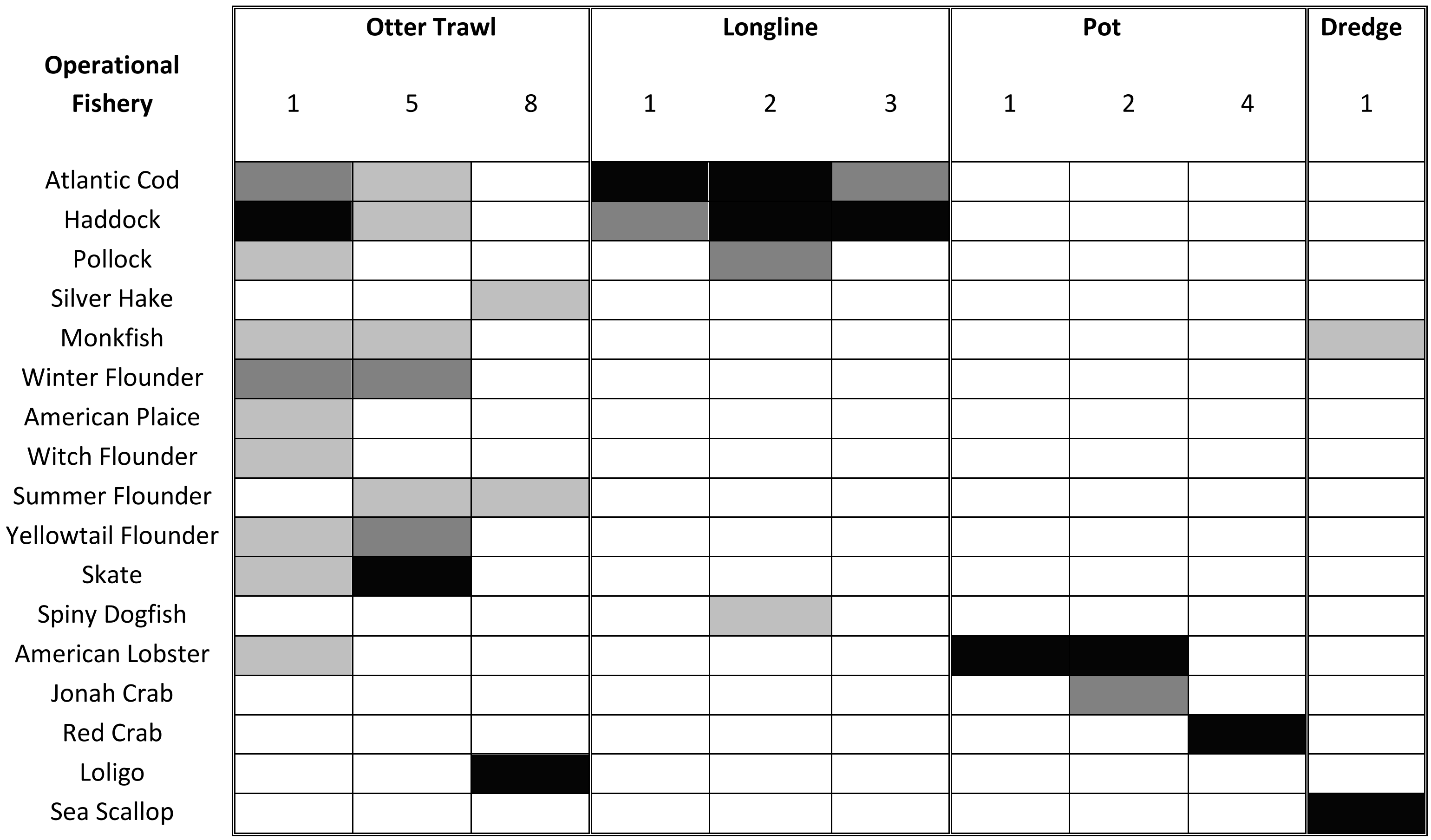


Figure 3. Operational Otter Trawl fisheries encompassing part or all of Georges Bank: (a) Operational Trawl Fishery 1; (b) Operational Trawl Fishery 5; (c) Operational Trawl Fishery 8. For further information on these designated operational fisheries, see Lucey and Fogarty (2010) and Table 4.1 for dominant species in the catch of each operational fishery.

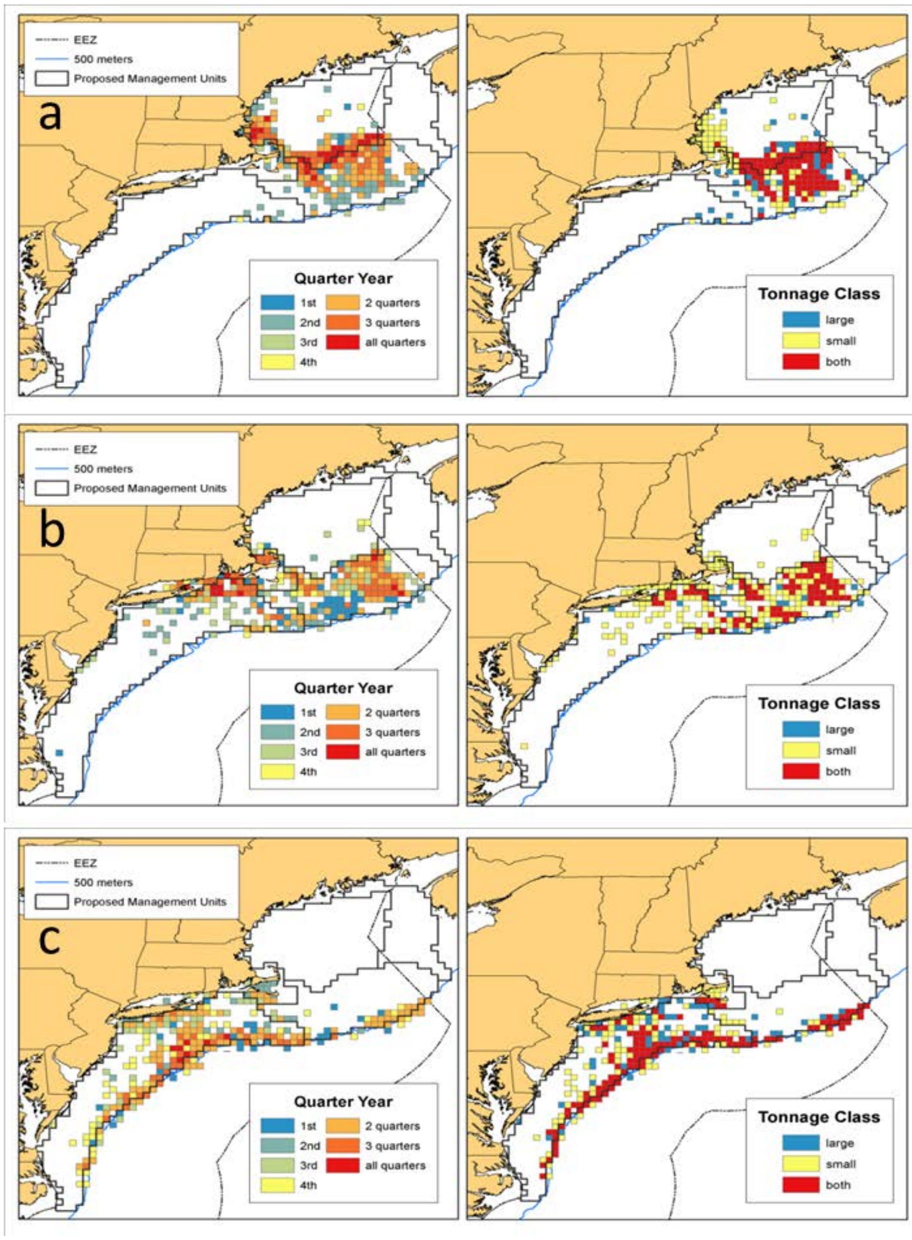


Figure 4. Operational Longline fisheries encompassing Georges Bank: (a) Operational Longline Fishery 1; (b) Operational Longline Fishery 2; (c) Operational Longline Fishery 3. For further information on these designated operational fisheries, see Lucey and Fogarty (2010) and Table 3.1 for dominant species in the catch of each operational fishery.

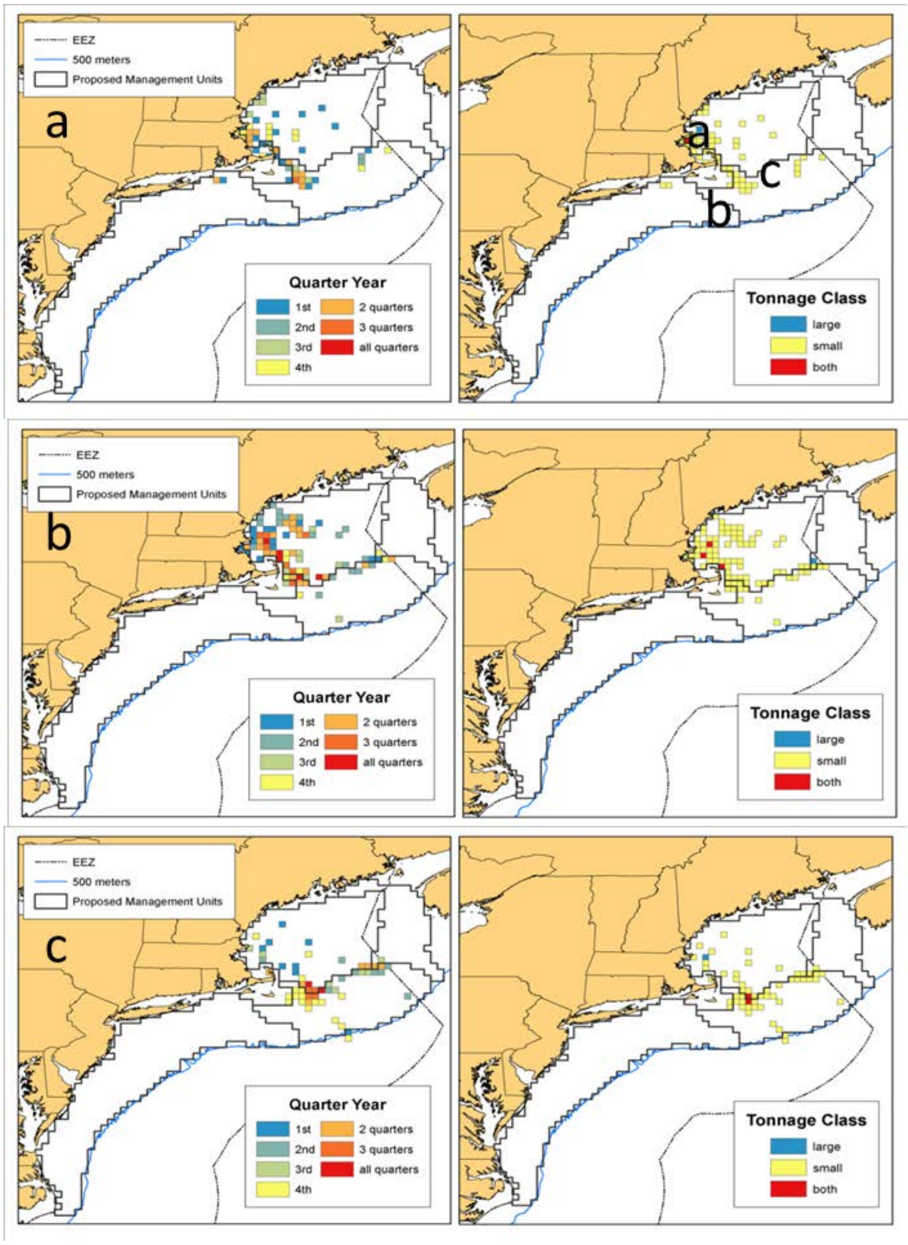


Figure 5. Operational Pot fisheries encompassing Georges Bank: (a) Operational Pot Fishery 1; (b) Operational Pot Fishery 2; (c) Operational Pot Fishery 4. For further information on these designated operational fisheries, see Lucey and Fogarty (2010) and Table 4.1 for dominant species in the catch of each operational fishery.

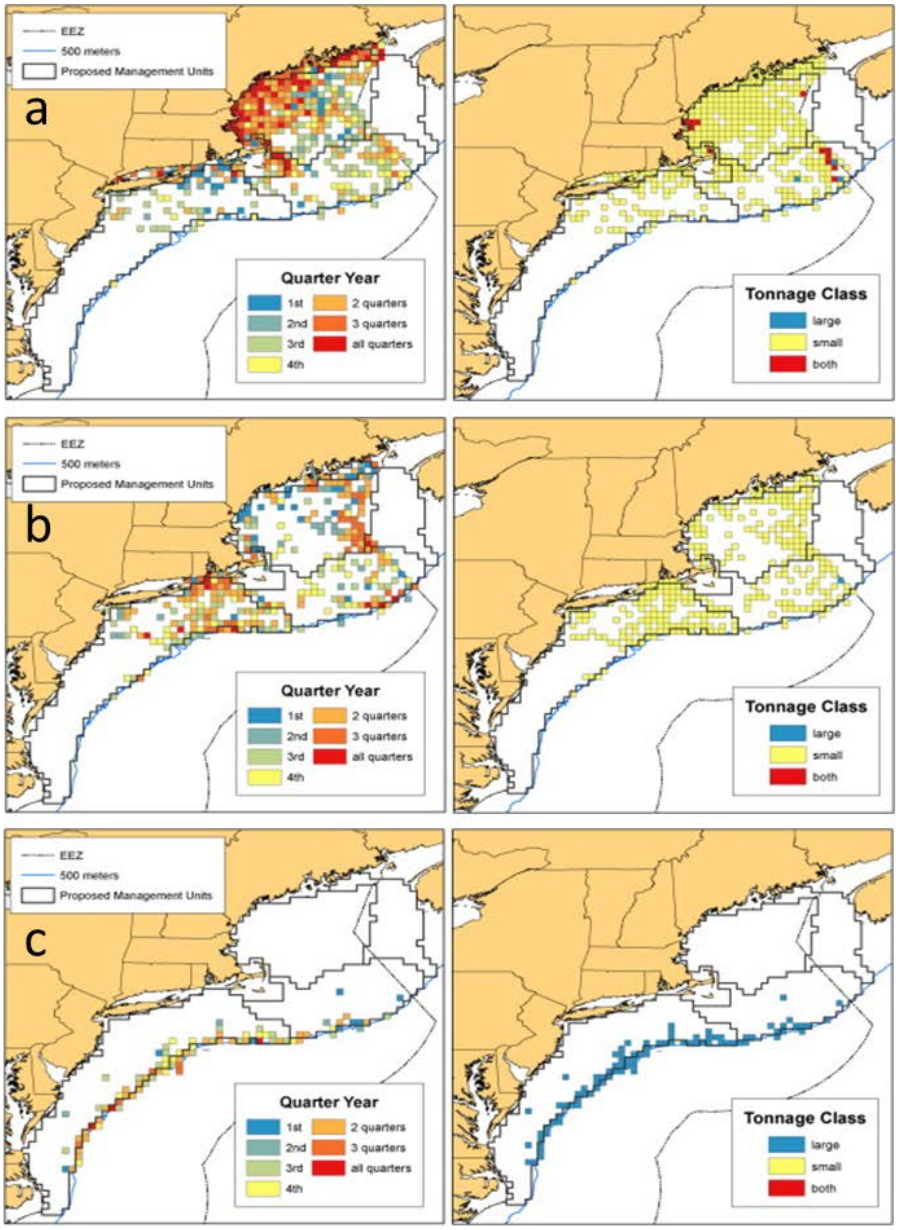
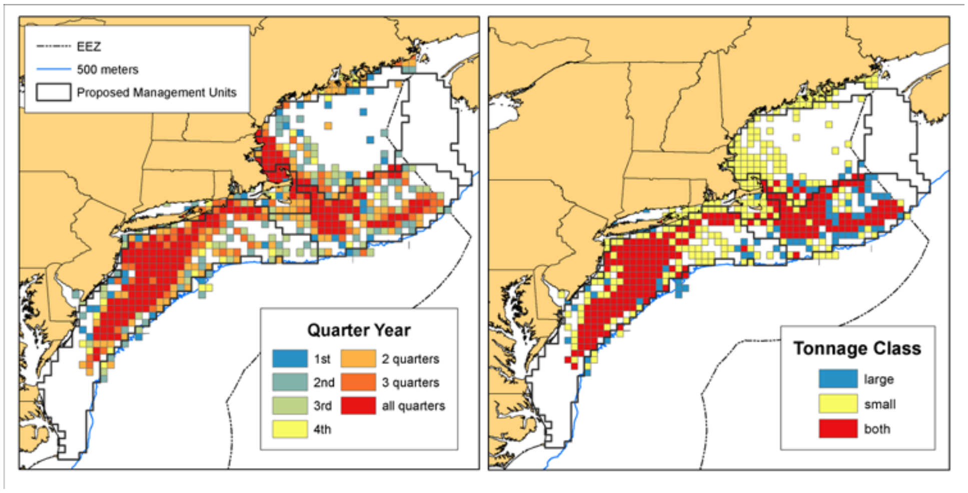


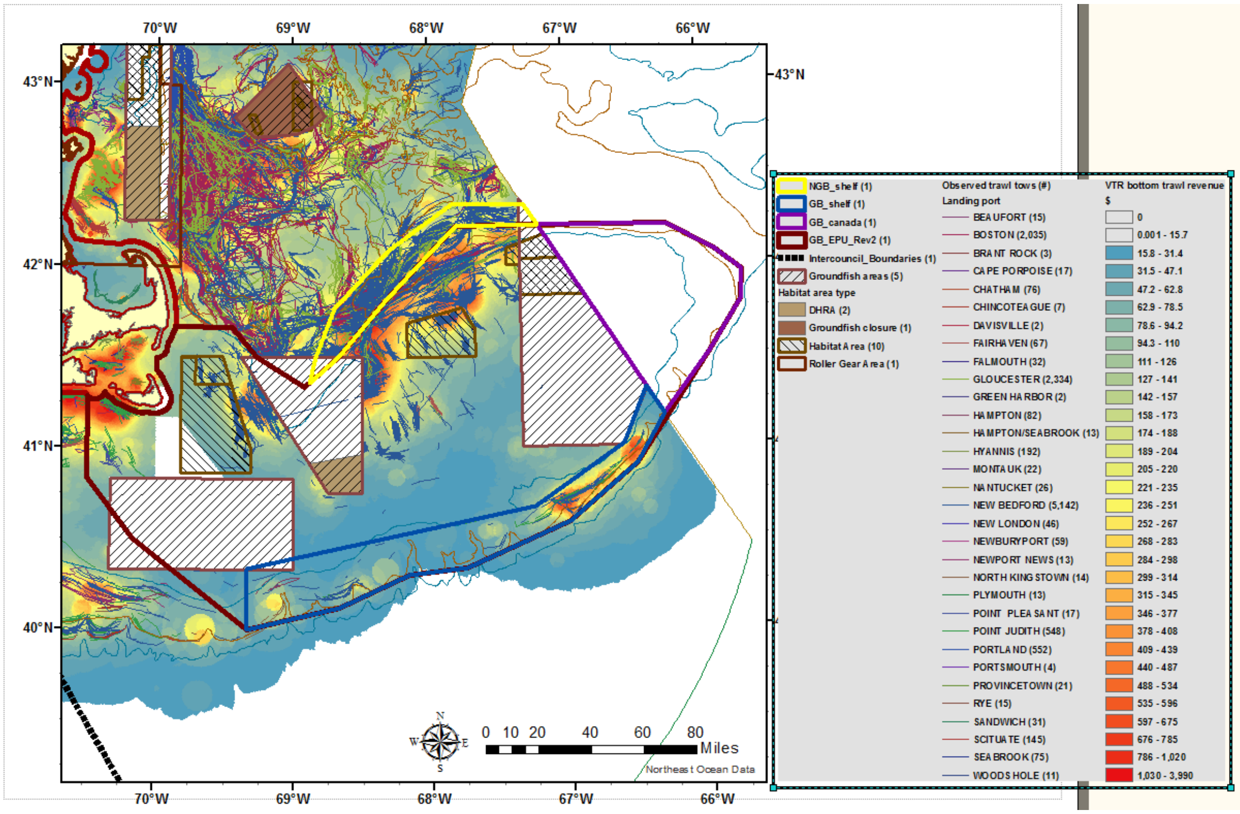
Figure 6. Operational Dredge Fishery 1 encompassing Georges Bank. For further information on these designated operational fisheries, see Lucey and Fogarty (2010) and Table 4.1 for dominant species in the catch of each operational fishery.



For the purposes of defining management units, the boundaries of a Georges Bank EPU can be defined on the basis of both biological (distribution of invertebrates, fish, marine mammals, sea turtles, and seabirds), physical (depth, bottom substrate, and temperature or water masses and circulation), and fishing activity. Ideally, the boundaries for the EPU should encompass the key components of the system and avoid cutting through areas of heavy biological and/or fishing activity.

The following analysis of observed and reported fishing distribution, fish distribution, and other species distributions suggests a Georges Bank EPU boundary shown in Figure 4.6. Areas in deep water along the shelf adjacent to the northern and southern edges of Georges Bank could be part of the Georges Bank EPU, but may require special management because the mix of fisheries and species overlap those on the shallower portions of the bank, but there are some important distinctions.

Figure 7. Potential Georges Bank EPU boundaries including special shelf, deeper water management areas north (yellow) and south (blue) of Georges Bank and Canada (purple). The data include observed bottom trawl commercial tows (2009, 2014) by port of landing and interpolated distribution of bottom trawl commercial landings revenue (2014).



6.3 Management Unit (or subunits) (MU)

A description of spatial boundaries and fisheries with allocated catch allocations and specific technical measures to regulate fisheries that occur there.

Although the intent is to manage stock complexes in an ecosystem production unit (EPU) as one with consistent rules and catch limits to achieve a single set of goals and objectives, there can be reasons to create subunits or special management zones to address more local ecological processes (e.g. vulnerable habitats, spawning, and protections for species of concern), or ways of fishing (e.g. small-boat vs. large-boat participation). These sub-units could be specified to pertain to certain permit conditions (see Section 9.3) or to manage effects on local ecological processes (see Section 9.4.1).

Ideally, the boundaries chosen would be defined by a commonality among fisheries occurring within the MU, rather than on a species stock definition. A single management unit would not cross EPU boundaries.

6.4 Species Complexes

Coping with complexity is a central consideration in any attempt to implement operational EBFM. We began this document by noting that one of the underlying causes of the difficulties in effectively managing mixed-species fishery resources in the Northeast may reside in the complexity of the system related to biological and technical interactions among managed species and our inability to exert exact control of fishing mortality in mixed-species fisheries. The ubiquity of tradeoffs that often remain unresolved in conventional single species approaches contributes to the difficulty in developing effective management strategies. In many instances, management targets derived from a single species perspective in which species are treated in isolation work at cross purposes when applied to assemblages of interacting species. One possible avenue for addressing these intertwined issues is to ask whether management actions directed at higher levels of ecological organization may offer a viable alternative approach to management of mixed-species fisheries.

Here, we identify Fishery Species Complexes as possible focal points for management. Species Complexes are defined with respect to the role played by species within an ecosystem. Our interest centers on Fishery Ecosystems defined as coupled social-ecological systems. For our purposes, a Fishery Species Complex is defined as species that are caught together, share common life history characteristics, and play similar roles in the ecosystem with respect to energy transfer. Because the species are caught together, they typically share similar habitat use patterns and, often, size characteristics. Accordingly, the concept encapsulates information on the catch characteristics and targeting practices of different fleet sectors and trophic guild structure.[1]

There is in fact a rich history of applying various forms of species aggregation in the assessment and management of fishery resources to address these concerns. One of the earliest applications of this approach was in fact on the Northeast U.S. Continental Shelf. Under the International Council for Northwest Atlantic Fisheries, a so-called two-tiered management system was implemented in 1973. Building on the development of an aggregate production model for all finfish species in the region, an estimate of total maximum sustainable yield for the Northeast Shelf was made and used to determine a proposed limit to the total removals from the system. A subsequent 'second-tier' analysis was undertaken to determine catch levels for each species to be allocated to national fleets engaged in the fishery such that the total limit would not be exceeded. Further analyses examining the dynamics of Species Complexes on Georges Bank were undertaken by Fogarty and Brodziak (1992), Collie and DeLong (1999) and Bell et al. (2014).

We re-examined the issue of defining Species Complexes for Georges Bank. Fogarty and Brodziak (1992) and Collie and DeLong (1999) employed a mix of taxonomic, trophic, habitat, life history, and fishery-related considerations in defining Species Complexes for this system. In many instances, the taxonomic considerations embed elements of the other four factors. Garrison and Link (2000) identified trophic guilds of fish and squid based on diet composition data obtained during NEFSC research vessel surveys. Ontogenetic shifts in diet composition were shown to be important for several species,; accordingly, some species were assigned to more than one trophic guilds depending on their size. Auster and Link (2009) employed these trophic guilds and examined the question of whether the guilds had

[1] Species Complexes and guilds can, under certain circumstances embody inter-related characteristics. For example, a planktivore Species Complex can be viewed as a conduit for energy flow from planktonic ecosystems to higher trophic levels within an aquatic ecosystem. Viewed as a trophic guild, planktivores are defined in terms of their similarity in diet preferences and requirements. In this context, species comprising a planktivore guild may be competitors and exhibit within-guild compensatory dynamics resulting in greater stability at the guild level than for the individual species within the guild.

remained stable over multi-decadal time scales. Bell et al. (2014) employed dietary guilds to define Species Complexes using a similar but somewhat consolidated set of species assemblage groups.

In the following, we adapt the trophic guild designations of Garrison and Link (2000) as the basis for defining the trophic-based element of Species Complexes for fish and squid included in their analysis. We consolidated some groups relative to the categories identified by Garrsion and Link. In particular, specialist feeding strategies on echinoderms and crabs noted by Garrsison and Link (2000) were combined with other benthivores. We added an additional trophic guild representing benthic organisms important in the fisheries (principally crustaceans and mollusks) and other species not routinely caught in NEFSC bottom trawl surveys (e.g Apex Predators).

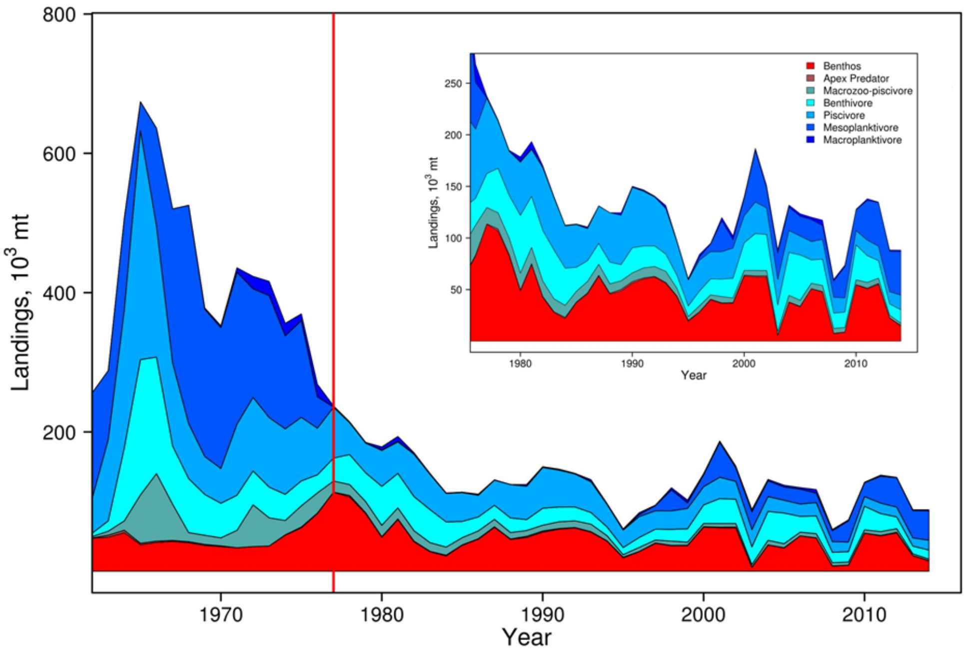
These modified Species Complex categories include the following groups:

1) Benthos (suspension and deposit feeders, principally crustaceans and mollusks)
2) Benthivores (predators of species in the benthos category)
3) Mesoplanktivores (predators of mesozooplankton, principally copepods)
4) Macroplanktivores (predators of macrozooplankton, principally amphopods but including decapod shrimp)
5) Macrozoo-Piscivores (predators of macrozooplankton and fish)
6) Piscivores (predators of fish species)
7) Apex Predators (typically large, fast moving predators that feed at the top of the food web)

A selected list of fish and invertebrate species on Georges Bank which are trophically-related to species caught by commercial or recreational fisheries, their designated trophic guilds and assigned Species Complexes is provided in Section 10.0. Information on the mean trophic level assigned to each species; its maximum size; whether it is considered to be ecologically but not currently economically important [i.e. an Ecosystem Component Species (ECS)]; and the dominant gear types in which the species is caught is provided in the table.

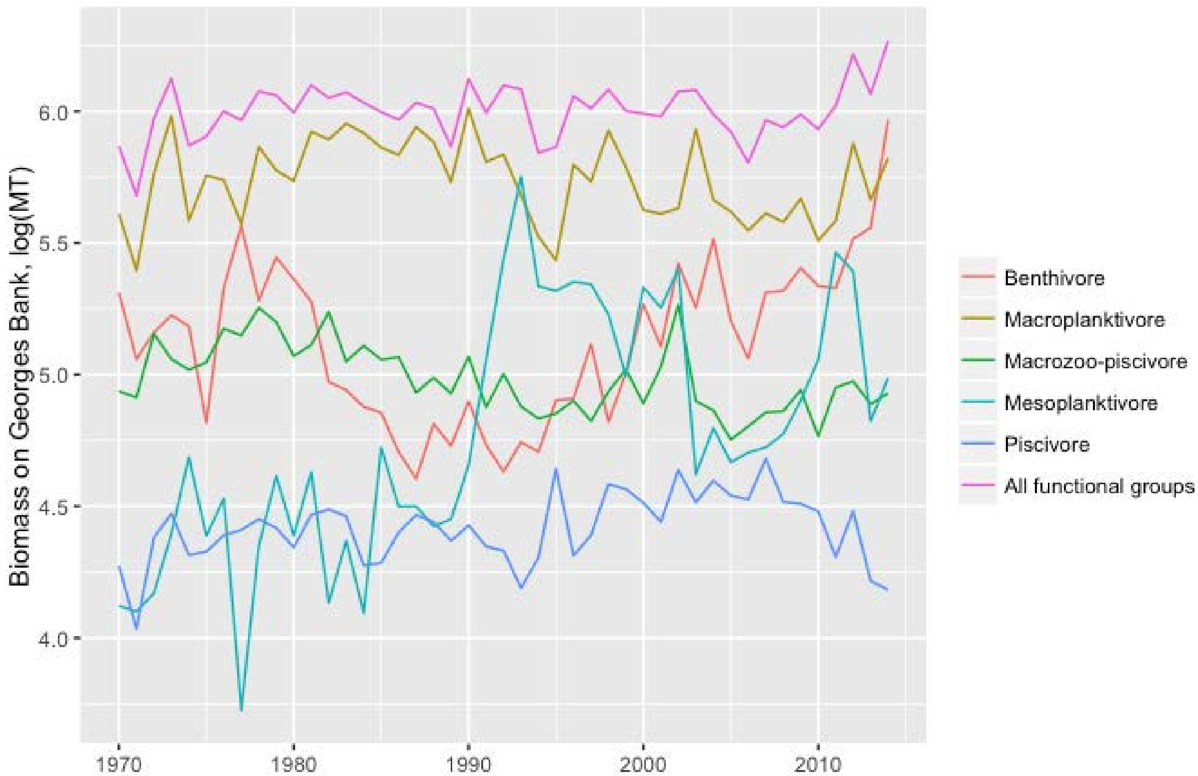
Reported landings on Georges Bank for the period 1964-2015 by the designated Species Complexes are shown in Figure 8. The initial impact of the distant water fleet, and the pattern of sequential depletion of species is clearly evident. By the mid-1980s, reported landings had stabilized (albeit at a slightly declining level).

Figure 8. Landings by Species Complex of species on Georges Bank 1964-2015. The vertical red line indicates the implementation of extended jurisdiction in 1977. The inset shows the landings from 1977-2015.



Estimates of the biomass of each Species Complex in NEFSC bottom trawl surveys adjusted for the area swept by the net and corrected for catchability are provided in **Error! Reference source not found.**. While declines in the biomass of most of the Species Complexes were observed during the period of operation of the distant water fleet on Georges Bank, subsequent increases in all components (albeit at different rates and overall levels) were evident in all. In many instances, species replacements within Species Complexes stabilized overall patterns of change within each. As overexploited species declined other, less intensively exploited, species increased (Fogarty and Murawski 1997).

Figure 9. Estimated Species Complex biomass based on NEFSC fall bottom trawl surveys on Georges Bank, adjusted by the area swept by the trawl and corrected for survey catchability using estimates reported by Brodziak et al. (2008).

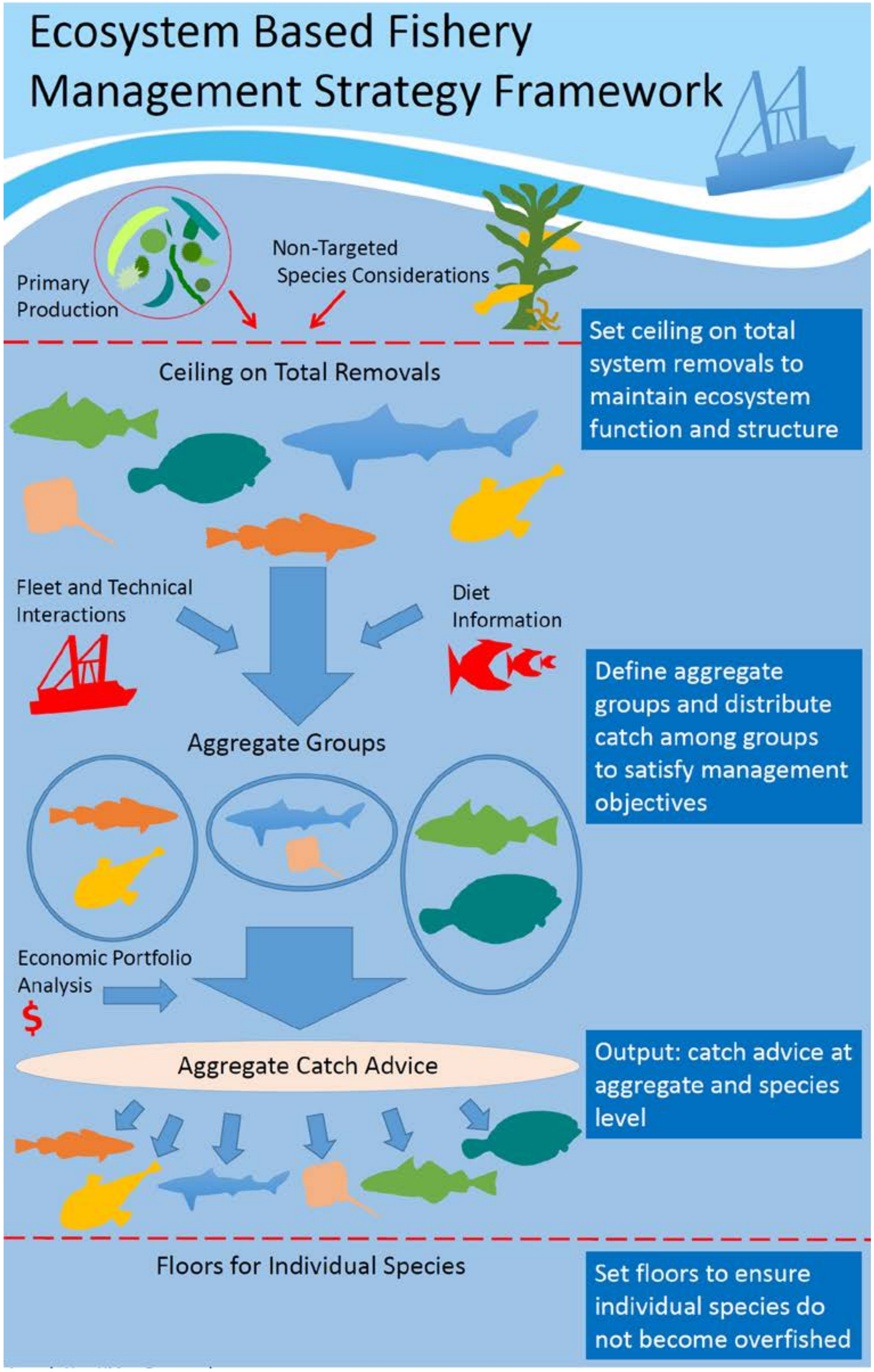


7.0 Operational Framework

In the preceding sections, we have described structural elements of one pathway toward the implementation of EBFM in the area of responsibility of the Council. The PDT focused on developing an eFEP for Georges Bank because most of the application of ecosystem models in the NE Region have focused on this area. Thus more models that are complete or well-developed are available here than for other areas with fisheries managed by the Council, in the Gulf of Maine or in Southern New England.

The key elements of the approach include the objective specification of the spatial domain [Ecological Production Unit (EPU)] to be managed, the identification of species complexes defined by trophic interactions and co-occurrence in fishing gear within the EPU, an overall system cap, and the critical role of management strategy evaluation in evaluating management options under consideration. In the following sections we build on these earlier elements and describe components of a potential operational approach to EBFM in the region including the identification of Ecosystem Reference Points establishing limits and targets for management and methods for determining catch levels in an ecosystem context (Figure 10).

Figure 10. Elements of the proposed hierarchical process for specifying Acceptable Biological Catch levels for species within defined Fishery Species Complexes

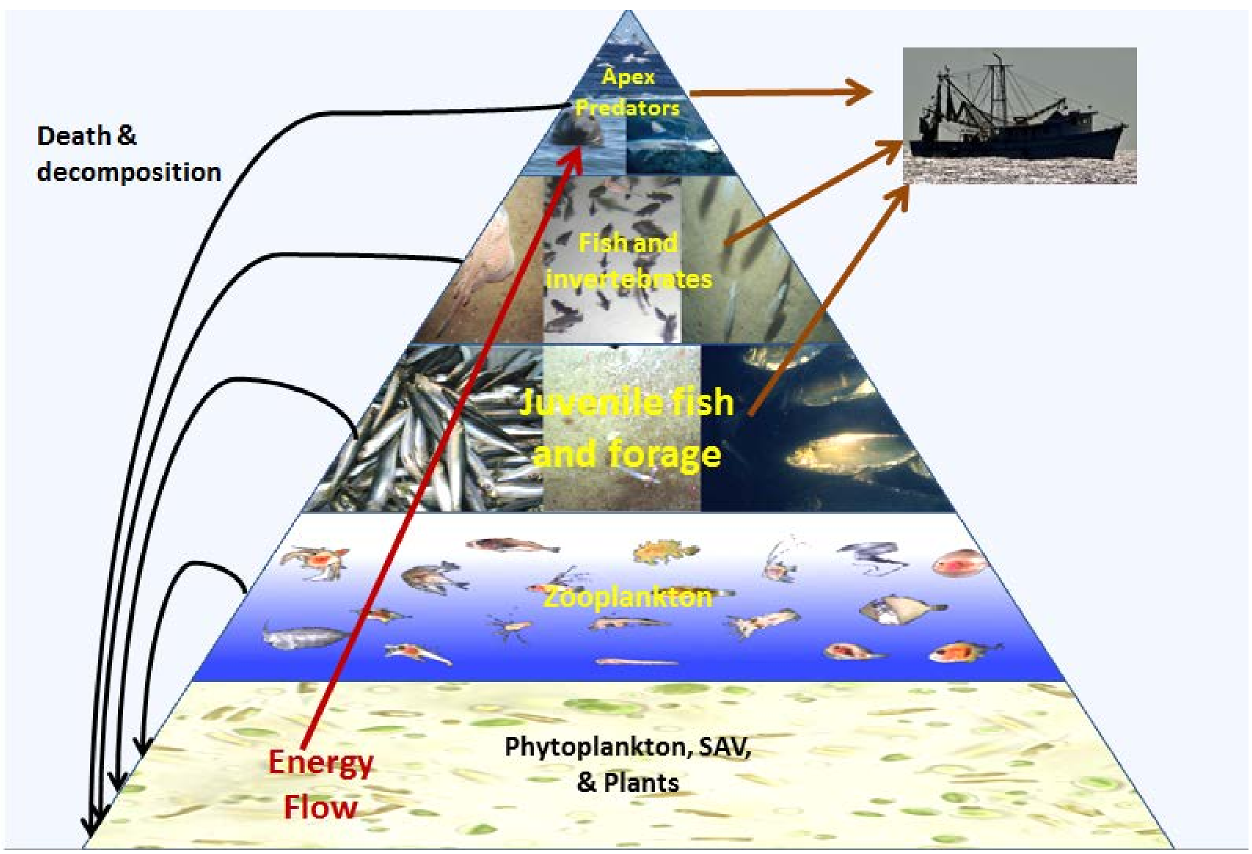


Consideration of energy flow and constraints on overall production in the system provide the foundation for the approach. In the identification of Species Complexes, the premise is that the whole is more stable than the parts (Figure 9). We attribute this greater stability to constraints related to patterns of energy flow and utilization and biological interactions within and between Species Complexes. Statistical averaging over a large number of species also contributes to this effect.

7.1 General FEP framework

The hierarchical FEP framework being developed by the Council and EBFM PDT for the Georges Bank EPU has a core constraint that total removals from fishing should not exceed a threshold percent of total productivity of the EPU. This constraint would reserve a proportion of the system productivity for other purposes within the ecosystem, such as supporting populations of higher trophic level species that are not captured by fishing (e.g. marine mammals, turtles, seabirds, etc.). Of course the calculation of the productivity must also include recycling of this energy through death and decomposition of these top level predators (Figure 11).

Figure 11. Schematic energy flow in a marine ecosystem, showing removals due to fishing. Other energy pathways such as emigration and losses to land from consumption in estuaries and guano are not shown.



Subordinate to ecosystem constraints on total removal, the composition of total removals will require management using catch limits specified by guild or functional groups of species. The catch composition specified by guild could allow flexibility and resilience to variability and change while achieving adequate forage availability, species diversity, spawning, and age structure.

Some species and stocks may need some additional limits to prevent a species or stock from becoming depleted or overfished, i.e. current biomass falling below a pre-specified limit which reduces ecosystem risk. Other technical measures (such as gear configurations and mesh, area closures, etc.) or special catch limits will be needed to improve yield (subject to the guild ecosystem constraints), enhance the opportunity for fish to spawn, maximize yield per recruit, build optimal age structure, and conserve essential fish habitat.

Any or all of these technical measures could be used to keep catch below ecosystem limits and/or address localized concerns (such as sensitive habitat, spawning activity, or localized depletion of forage fish). As with total ecosystem removals, all fishery management authorities should strive to build a general consensus about what the optimal mix of results should be and abide by the catch limits for the guilds in the EPU.

On the US portion of Georges Bank, most stocks and total fishery removals are managed by the NEFMC. Monkfish and spiny dogfish are jointly managed with the MAFMC, while ASMFC-managed lobster has a significant economic contribution and MAFMC-managed summer flounder, loligo squid, black sea bass, and scup are notable components of Georges Bank EPU catches. A full list of species, management authority, trophic category, and guild assignment is given in Section 2.1.2.1 of the eFEP for the Georges Bank EPU.

Within the FEP, specific management units (MU) could be identified based on a region having common fishery characteristics. Catch limits for ecosystem guilds would be allocated to MUs (and vessels authorized to fish in them) based on (relatively) recent catch histories. One possible configuration would create separate MUs for the Great South Channel (where there are more tuna and recreational anglers, and higher whale and marine mammal densities), for Eastern Georges Bank (where groundfish, lobster, and scallop commercial fishing is more important) and the Georges Bank southern shelf (where silver hake, squid, and red crab fishing are more important).

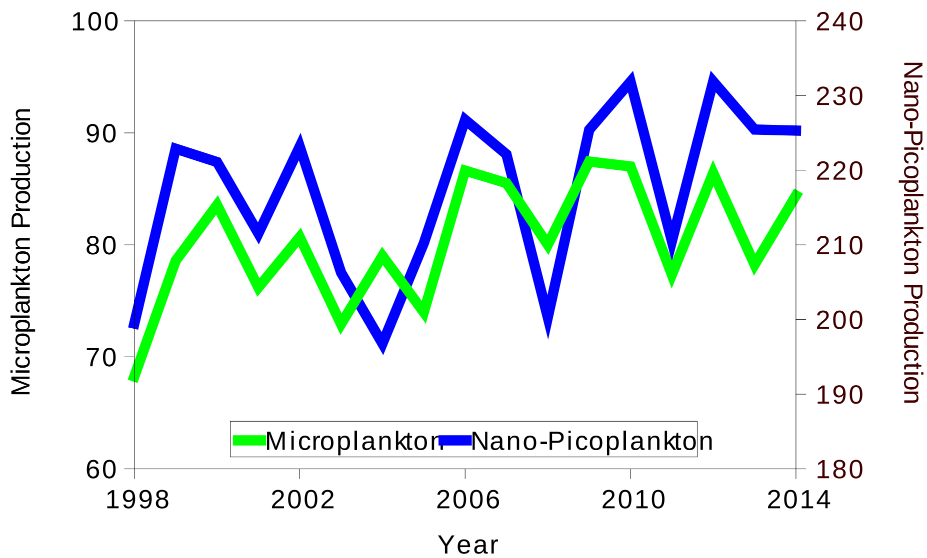
7.2 Ecosystem Reference Points

The production in an ecological system is ultimately constrained by the amount of energy available at the base of the food web. The production levels manifest throughout the food web reflect the joint effects of energy inputs and interactions among the components of the system, including humans. Iverson (1991) proposed an ecosystem reference point based on the fraction of 'new production' in the system. New production is the production generated by the renewal of nutrients in the water column and its uptake by phytoplankton. A modification of Iverson's approach focuses on the fraction of total production attributable to microplankton (species > 20 μ) principally composed of diatoms and large dinoflagellates. These species are dominant during the spring bloom period resulting from nutrient regeneration and increasing day length. We define a limit exploitation reference point for the system as the fraction of production by microplankton in the system (see Fogarty et al. 2016). Production by smaller-sized phytoplankton (nano- and picoplankton less than 20 microns in size) generally involves pathways through the microbial food web, depends substantially on recycled nutrients and do not contribute to higher trophic levels. A substantial fraction of the microplankton production goes directly into the grazing food web involving suspension feeding bivalves of economic importance (e.g. scallops, and clams and meso-zooplankton (e.g larger copepod species) which are grazed by planktivores such as herring, mackerel, and butterfish. In contrast, the transfer of energy from the microbial food web to species of economic importance involves at least one or two additional steps in which energy is dissipated before reaching the upper trophic levels. Accordingly, although the production of nano- and picoplankton accounts for the dominant share of total phytoplankton production in the sea, the role of microplankton production in the dynamics of upper trophic levels is comparatively very important.

Remote sensing satellite data allows for estimation of biomass and production for these phytoplankton size classes based on their spectral signatures. The estimated levels of production by the larger-sized phytoplankton Species Complexes and that of the smaller size classes are depicted in Figure 12. The estimated level of primary production on Georges Bank has increased since 1998 (Figure 12) based on satellite monitoring although the estimated ratio of microplankton to total production has remained more stable with a mean of 0.27 during the period 1998-2014.

An appropriate limit exploitation reference point for the system as a whole therefore is 27% of primary productivity. However, to ensure that the food requirements of other components of the ecosystem, including protected species such as marine mammals, sea turtles, and sea birds are met, a target level of exploitation should be established that is lower than this limiting exploitation rate. For example, a target exploitation rate of two thirds to three quarters of the limiting level would result in an exploitation rate of approximately 18-20%.

Figure 12. Estimates of primary production (gC m-2 yr-1) for microplankton and nano-picoplankton on Georges Bank (Kimberly Hyde, NEFSC, personal communication



In addition to direct examination of the primary production, ecosystem reference points have been developed from multispecies models for Georges Bank. Brown et al. (1976) applied an aggregate production modeling approach for the entire Northeast Continental Shelf System resulting in estimates of system-wide Maximum Sustainable Yield and an estimate of the level of fishing effort resulting in MSY for the system. A Georges Bank model with 21 species was examined to illustrate tradeoffs between yield and biodiversity in exploited marine ecosystems (Worm et al. 2008). It was shown that maximizing ecosystem yield resulted in numerous collapsed species (defined as species falling below 10% of their unexploited biomass levels), however, harvesting roughly 90% of eMSY greatly reduced the risk of species collapse. Similar results were shown by Gaichas et al. (2012) using a different multispecies model for Georges Bank.

The eFEP adopts a modification of the Iverson (1991) productivity method for establishing the ecosystem reference points from which an overall system catch cap can be developed, but recognizes that other methods could be employed.

7.3 Catch Limits

The EBFM PDT proposes a hierarchical approach to establishing catch limits that starts with the establishment of an overall cap or ceiling of removals from the system as a whole. A similar constraint was employed in the 1973 ICNAF Two-Tier Management System described earlier and is now employed in management of groundfish resources in the Gulf of Alaska and the Bering Sea (NPFMC 2018a and 2018b). This ceiling could be adjusted according to changing patterns of production in the system. Catch limits would be set for each Species Complex and the sum of the Species Complex catch limits could not exceed the system-level ceiling (overall catch cap). This will require biomass estimates for each Species Complex and a target level of exploitation for each that will meet the ceiling constraint. The biomass estimates can be generated by multispecies assessment. It is also possible to use model-free estimation methods based on direct estimates of biomass from survey or other sources (for a list of feeding guilds and Species Complexes, see Figure 9). We recommend the use of multiple assessment models and estimation methods where feasible and to employ methods of multimodel inference.

To provide protection for individual species within Species Complexes, we define biomass levels below which species are deemed to be at risk. The most broadly applicable method available to inform these thresholds is based on survey estimates of biomass. Species falling below specified levels would be defined as at risk and requiring remedial management action for protection. Candidate threshold levels under consideration include a sustained drop below the 20^{th} percentile in survey biomass over the time series for teleosts and below the 30^{th} percentile for elasmobranchs (whose life history characteristics make them more vulnerable to exploitation). Threshold levels for defining individual species at risk would be made based upon the best scientific advice and Council policies.

The Council could make other choices for biomass floors that are related to risk assessment, considering the species vulnerability, productivity level, economic value, and/or ecosystem function. A final consideration in setting target catches involves maintaining stability. The NEFMC recently identified stability as a core component of its risk policy. In its Risk Policy Roadmap, stability is defined as “Evaluating the trade-offs of minimizing variability while achieving the greatest overall net benefits to the nation”, and that “Metrics that monitor variability from year to year, e.g. in quotas, should be developed” (Risk Policy Working Group 2016). The overarching goal, then, is to assess the trade-offs between generating a high flow of benefits and the ability to ensure that flow of benefits can be generated in a stable and sustainable manner.

In economics, modern portfolio theory was developed to assess this exact trade-off (Markowitz 1952). Portfolio analysis measures the extent to which financial assets change relative to each other, with the idea that in a well-balanced portfolio a decrease in the value of one asset will be off-set by an increase in another. The framework has been extended to assess trade-offs in fishery management (Edwards et al. 2004, Sanchirico et al. 2008), in that species and Species Complexes can be viewed as generating a flow of benefits whose stability can be assessed in a similar manner to financial assets.

Jin et al. (2016) employed portfolio theory to assess historical performance in the Northeast Large Marine Ecosystem, and this model can be coupled to the multispecies models or direct estimation methods based on survey data in order to provide measures of stability and returns for the Georges Bank system. In particular, the ceiling or caps for the system as a whole and the floors as developed for each species can be used as constraints in the portfolio optimization, in order to ensure sustainability at the species level.

7.3.1 Resource Sharing Among Management Units in an EPU

The NEFMC would serve as lead management authority for the Georges Bank EPU and management units within it (see preferred approach and discussion in Section 9.2). The Georges Bank EPU is entirely within the region that Congress identified as being managed by the NEFMC (See §600.105; http://www.ecfr.gov/cgi-bin/text-idx?SID=26405a30bb459dd8f241d50c77f40d8e&mc=true&node=se50.12.600_1105&rgn=div8) and the majority of species that the fishery catches on Georges Bank are managed by the NEFMC.

Similar to the TMGC framework, a management board or advisory panel could develop a Georges Bank EPU resource sharing agreement as well as technical measures that would apply to MU fishing activities. The resource sharing could be based on a combination of survey and fishery data for each Species Complex of Georges Bank EPU species. The NEFMC would review and approve of these recommendations under its Georges Bank EPU FEP. Allocations and measures that pertain to Georges Bank EPU species not managed by the NEFMC would also require review and approval by the appropriate management body (i.e. MAFMC, ASMFC, NMFS-HMS). Although the role of the TMGC would continue to focus on the allocations of cod, haddock, and yellowtail flounder on Eastern Georges Bank, its role could also be expanded to include other ecosystem components of joint interest to both countries.

7.4 Overfished stocks

Although criteria for defining overfishing at an ecosystem level are only now emerging, approaches based on ecosystem indicator reference points have received increasing attention (e.g. Link 2005). Tudela et al. (2005) and Libralato et al. (2008) have constructed indices of ecosystem overfishing incorporating information on the primary production appropriated by fisheries and the mean trophic level of the catch. These indices were based on classification systems using independently assigned ecosystem status levels (overfished, sustainably fished) using the criteria of Murawski (2000) in conjunction with PPR and mean trophic level. Murawski (2000) suggested that an ecosystem could be considered overfished if one or more of the following criteria were met:

- Biomasses of one or more important species assemblages or components fall below minimum biologically acceptable limits, such that:
  1) recruitment prospects are significantly impaired,
  2) rebuilding times to levels allowing catches near MSY are extended,
  3) prospects for recovery are jeopardized because of species interactions,
  4) any species is threatened with local or biological extinction;

- Diversity of communities or populations declines significantly as a result of sequential ''fishing-down'' of stocks, selective harvesting of ecosystem components, or other factors associated with harvest rates or species selection;

- The pattern of species selection and harvest rates leads to greater year-to-year variation in populations or catches than would result from lower cumulative harvest rates;

- Changes in species composition or population demographics as a result of fishing significantly decrease the resilience or resistance of the ecosystem to perturbations arising from non-biological factors;

- The pattern of harvest rates among interacting species results in lower cumulative net economic or social benefits than would result from a less intense overall fishing pattern or alternative species selection;

- Harvests of prey species or direct mortalities resulting from fishing operations impair the long-term viability of ecologically important, non-resource species (e.g., marine mammals, sea turtles, seabirds).

Biomass floors for individual stocks would serve as reference points to trigger action to prevent further depletion and/or being overfished. Although their catch would be part of a stock complex limit, special catch limits or measures would apply when stock biomass is less than a specified threshold. Strategies for applying special catch limits is provided in Section 9.1.2. Also, incentive-based measures (described in Section 9.1.3) and spatial management measures (Section 9.4) could apply to protect stocks that are more vulnerable to fishing due to high value and/or low productivity, or low resilience to recovering from low biomass.

8.0 Management Strategy Evaluation

Management Strategy Evaluation, or MSE, is a process or tool that has three parts. One part is a set of strategic goals and operational objectives that describe what managers would like to achieve. Scientists, managers, and stakeholders develop a set of performance metrics (e.g. risk levels, biomass levels, average fish size, profit, minimum abundance of apex predators, etc.) that are associated with the operational objectives. Because the goals and objectives often cannot be achieved simultaneously, there are tradeoffs to be considered.

A second part of the MSE is one or more operating models that describe the productivity and resilience of fish populations (see figure below), with a range of factors or assumptions that bracket the expected variation and/or uncertainty about these factors or assumptions. Fish populations for these operating models are simulated, so that we understand what 'truth' is for a population with 'known' characteristics, enabling us to understand the real effect of management procedures to be tested. The operating models can also introduce a 'known' amount of variation, so scientific uncertainty can be estimated.

A third part is a set of management procedures, typically a variety of harvest control rules and strategies that limit the size and amount of fish that may be caught by the fishery. Also in this third part, assessments are typically applied that estimate population size and future catch limits. The second and third parts of the MSE are re-run hundreds or thousands of times in a cycle to evaluate the how well candidate management procedures perform, i.e how frequently the performance metrics meet or exceed the operational objectives.

With the goal of evaluating different assessment and management methods, a standard set of information must be developed against which all methods can be compared. For the Fishery Ecosystem Plan of the Georges Bank ecological production unit, the standard set of information will be derived from a virtual representation of Georges Bank via an ecosystem model, denoted as the operating model, which would simulate all the known and essential components of the ecosystem. It would contain all the measured and derived quantities for the population dynamics of the interacting species in the system, such as growth, mortality, size-at-age, and catch. For the purposes of evaluation, the operating model is considered a representation of the "true state" of the ecosystem and the different population assessment methods can be examined based on their ability to approximate the known values.

To explore the performance of different management methods, the operating model will be used within a larger MSE. The NMFS National Working group on Management Strategy Evaluation has defined MSE as follows (March 2016 Draft):

> *"Management strategy evaluation (MSE) is a process for exploring the consequences of alternative management approaches on a set of objectives established in collaboration with appropriate stakeholder groups. Simulation testing is at the heart of the process. A typical application of an MSE consists of using a set of operating model(s) that incorporate sufficient complexity to simulate variability in a state process (e.g., fish population, ecosystem or economic dynamics), and an estimation model to perform virtual data collection, analysis and management advice. The effects of alternative management strategies (e.g., data collection systems, assessment methods, harvest control rules, adapting management to a changing climate, protected resource take reduction strategies, etc.) can then be examined relative to multiple objectives associated with the system (e.g. catch, abundance, economic gain, annual variation in catch, emergent ecosystem properties, conservation level achieved, biodiversity etc.). The MSE process is iterative and is most effective when stakeholders are involved throughout the*

process. Outcomes from an MSE may be applied directly in management, or may be more exploratory in nature."

In this context, the operating model simulates realistic dynamics that are affected by management methods implemented using pre-defined harvest control rules in order to evaluate a particular strategy. The operating model simulates annual values for the numbers and biomass of the different species which are then sampled with error to simulate catch records and trawl surveys to inform separate assessment models. The output of the assessment models trigger the harvest control rules for the management method being examined. The harvest control rules then feed back into the operating model by altering the fishing mortality and impacting the abundance of the different species. After several iterations of simulations, different management strategies can be evaluated based on their ability to achieve a set of pre-defined management objectives. It is important to note that MSEs do not optimize outcomes but rather allow for the evaluation of the relative risk and tradeoffs between strategies.

A key feature of the MSE process is that it requires the input of stakeholders to determine objectives. To function effectively, models for MSEs are developed after the objectives are clearly specified. Further, multiple operating models capable of addressing the specified objectives may be necessary to incorporate uncertainties in current or future system states within an MSE. Therefore, the primary characteristic that an MSE operating model suite must possess is the ability to output measurable quantities (performance measures) directly related to the specified objectives (Table 8. Species Complexes of Georges Bank EPU species.Table 8). No "off the shelf" tools exist that work for every MSE. It is important to modify or develop the right tools for the job as specified through an interactive, stakeholder process.

Table 2. Key attributes derived from operating models of Georges Bank for the FEP

Key Attributes
Abundance/biomass estimates for Multi-species/multi-Species Complexes by age/size
Species interaction terms - predation and competition coefficients
Climate interaction terms
Climate and species interaction dependent recruitment
Fishing mortality
Fishing selectivity and catchability
Resource dependent growth
Ability to incorporate multiple fleets

In the Northeast US, we are fortunate to have a wide range of existing models that can be used as the base for MSE. The models include ecosystem interactions and can output performance measures relevant to basic biological and societal objectives; the process does not have to start from scratch. As of the writing of this eFEP, the three most applicable models are a mass balance Ecopath model, a length-structured multispecies model, and an end-to-end Atlantis model. Each is discussed in more detail below. Note that all three models would likely need some modifications given a clearly defined set of biological and societal management objectives. These models are presented to demonstrate their attributes but should not be considered the only potential models that could be used. The list should be amended and/or expanded as new models and techniques become available.

8.1 *Candidate Operating Models – strengths and weaknesses*

8.1.1 Ecopath – mass balance

Ecopath (EwE,) is a mass balance snapshot that represents the flow of energy through a system. It does this by balancing the consumption and production of the various nodes within the model. The Ecopath snapshot can also be used for dynamic simulations using the Ecosim extension of the software package. There is an existing Ecopath model of Georges Bank developed as part of the Energy Modeling and Analysis Exercise (EMAX, citation needed here). This model is highly aggregated with low fleet resolution. The model was never run dynamically and some work would be necessary to ensure realistic dynamics. There are plans to update the model using more resolved fleets and species. It is important to note that there is no true size structure in EwE models although they allow for a species to have multi-stanza parameters. These multi-stanza groups are typically used when there are large ontogenetic shifts either in diet or exploitation. Base EwE models are also not spatially explicit although there is the Ecospace extension that would allow for some spatial dynamics. However, there is work in the region developing an R implementation of EwE which will allow movement between models using an emigration term.

8.1.2 Hydra

Hydra (Gaichas et al. 2016) is implemented in ADMB (Fournier et al. 2012) and simulates a number of (currently ten) species with length-structured population dynamics, predation, and fishery selectivity with fishing mortality coming from (three) effort-driven multispecies fleets. Multiple forms for growth and recruitment are implemented in the operating model so that each species may have different combinations within the model structure (e.g. von Bertalanffy growth with Ricker recruitment, exponential growth with Beverton Holt recruitment) and environmental covariates for each function can also be included. There is no feedback between prey consumption and predator growth in Hydra. Species grow regardless of whether they consume sufficient prey.

8.1.3 Kraken

Kraken is a software package created in C++ (specifically QT C++) that allows the user to use a number of different functional forms to create single species, multi-species, and functional group production models. The models can replicate currently published models from a simple single species Lotka-Volterra model (Lotka 1925, Volterra 1926) up through MS-PROD (Gamble & Link 2009) which incorporates predation, interguild and intraguild competition, and exploitation by fisheries, as well as AGG-PROD (Gamble & Link 2012) which is built with functional groups. Functional forms including or excluding carrying capacity can be chosen for growth of the populations, interguild and intraguild competition, and Types I, II, and III functional forms for predation with the ability to model feedback by prey on their predators. Multiple fleets can be modeled and can use a simple time series of catch for each species or group in the model, an exploitation rate, or a catchability/effort based functional form. Environmental covariates can be added to improve model performance, by affecting the growth rate or carrying capacity of a species or group. Finally, stochasticity can be applied to growth or catch in the model. A genetic algorithm can be used to estimate parameters given biomass/abundance and catch time series.

8.1.4 Atlantis

Atlantis is an end-to-end biogeochemical model (e.g. Fulton et al. 2011). NEFSC developed an Atlantis model for the Northeast US (Link et al. 2010). As an end-to-end ecosystem model, Atlantis incorporates physical processes (e.g. sunlight, geochemistry, water flows, temperature, salinity, nutrients), biological processes for phytoplankton through whales (e.g. age structure, multiple recruitment functions, predation, natural mortality), and human dimensions (e.g. fishing effort, vulnerabilities of fish to a fishery, discard, bycatch, ports). Atlantis is computationally complex and requires a much longer run time than the other models. There are currently efforts underway to upgrade the original Atlantis NEUS model to more closely align Species Complex structure with managed species in the region and to update the model to newer version of the code to take advantage of recently added model features..

9.0 Prototype Ecosystem-Based Management Strategy for Georges Bank

9.1 Ecosystem reference points, control rules, and catch limits

The concept that the Council is putting forth for managing stocks that are caught in appreciable amounts within the Georges Bank EPU is to group stocks by trophic (e.g. common diet and predators) and life-history (e.g. longevity, age at first spawning, body shape, behavior that places the fish on the bottom, mid-depth, surface, etc.) characteristics. Generally, the sum of catch limits for a stock complex is expected to be more stable than for individual stocks (i.e. single stock catch limit management).

There are 74 stocks within the Georges Bank EPU that are caught in appreciable amounts by the commercial, recreational, and pelagic fisheries. To provide an example using trophic and life-history characteristics, the Council has classified the Georges Bank fish stocks into proposed stock complexes as shown in the table below. Although the stock complexes should be stable over time, managers may want to reclassify one or more stocks into a different stock complex, depending on analysis of harvest policies to achieve management objectives.

The discussion below in this section outlines a potential framework for setting catch limits. The actual amount of catch to be allocated to fishermen via fishery functional groups (species caught together in a defined fishery) would depend on the biomass of the stock complexes (which can be updated annually via survey indices or other measures of biomass) and the shape of the harvest control rule. Using operating models such as those described in Section 7.0, a wide variety of harvest control rules that account for trophic and technical interactions can be tested for their performance relative to the goals and objectives defined by managers.

As described in more detail in Section 7.0, the catch advice framework would consist of the following elements and potential approaches for setting catch limits are described below.

1) A limit on total EPU removals by all fisheries, defining ecosystem overfishing (see Section 9.1.1.1). The sum of stock complex catch limits and catches should not exceed this amount on an annual basis.
2) Catch limits for stock complexes, defining overfishing and being analogous to the Overfishing Level (OFL) and Annual Catch Limit (ACL) that are described in National Standard 1 (see Section 9.1.1.2).
3) Biomass floors for stocks, defining when a stock is considered overfished (see Section 9.1.2) and potential rebuilding management approaches for stocks that are a member of an EPU stock complex. This biomass floor may include new considerations and therefore have a different basis and value from existing definitions of when a stock is overfished. The threshold, however, would apply to the entire stock area, not just the portion that is found within the EPU boundary.

9.1.1 Catch limits for total ecosystem removals and for stock complexes

The goal of a Fishery Ecosystem Plan (FEP) is to provide catch advice intended to meet objectives associated with producing optimal yield from fisheries in an ecosystem production unit (EPU), while taking into account the role of the fishery and fished stocks in the ecosystem.

Catch advice under a FEP would be similar to current single-species advice, but would be provided at the level of a stock complex (see box). As they are now, setting catch limits for stock complexes will require estimates and possibly forecasts of total stock biomass. The Fishery Data for Stock Assessment Working Group Report document (https://s3.amazonaws.com/nefmc.org/6b.-181119_Draft_Fishery-Data-for-Stock-Assessment-Working-Group-report-with-appendices.pdf) presented by Dr. Steve Cadrin (https://s3.amazonaws.com/nefmc.org/6a.-Fishery-Data-for-Stock-Assessment-Council-Presentation.pdf) provides an excellent explanation of the source and use of various data to estimate stock biomass and mortality.

Stock complexes for this process are defined as groups of species that share similar diet and habitat niches and may also have similar life-history characteristics. Stock complexes that are caught together in a particular fishery may be allocated together as a fishery functional group

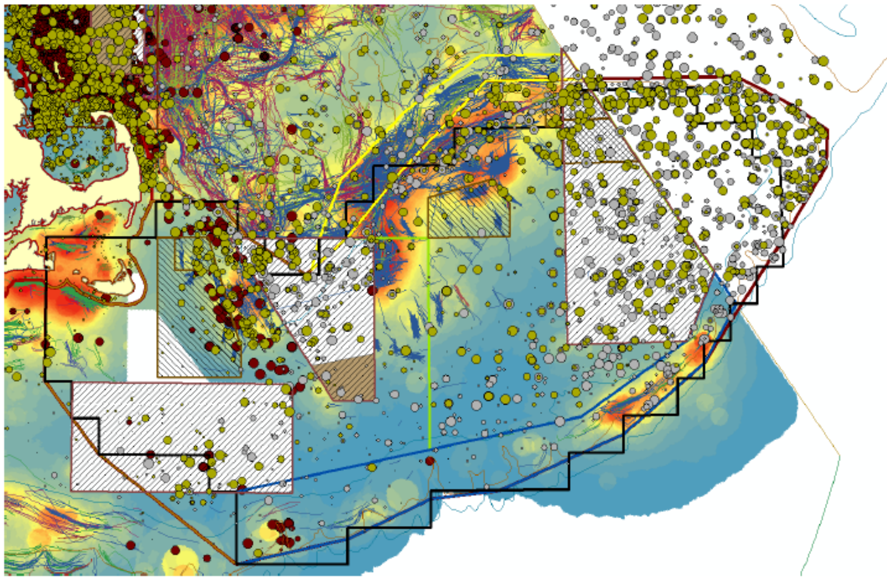
Using best available science, these estimates can come from a variety of sources (see the following list), as they are now or using new science that accounts for the favorable or adverse effects of expected abundance of trophically-related species. The biomass estimates and forecasts may be for single stocks or grouped stocks as needed.

1. Multi-stock assessments and forecasts: A set of analytical assessments that estimate trends in biomass and mortality for a group of species. Often, they would account for the effects of predation and prey availability.
2. Single stock assessments and forecasts: Individual analytical assessments of stock biomass and mortality. This is the form of stock biomass estimation that is most commonly used to set stock-by-stock catch limits.

Each of the options described below should be viewed as direct extensions of current approaches for providing management advice. For example, aggregate production models apply the same general methods to groups of species that are currently used for individual stocks.

The process of developing FEP catch advice begins with spatial management coordinating the science and regulations in a defined geographic area (for example see https://s3.amazonaws.com/nefmc.org/Document-2b.-Providing-catch-advice-for-a-fishery-ecosystem-plan-eFEP.pdf). Although the approaches for developing catch advice described below are general, the focus of the catch advice procedures is intended to apply to the Georges Bank EPU. Alternatives for the specific boundaries of the management area for the EPU(s) could be calculated based on distribution of fishing activity and distributions of trophically-related species (Map 1).

Map 1. 2014 bottom trawl (circles), recreational cod (red) survey cod (duck green) and haddock (grey) distributions overlayed on estimated bottom trawl revenue (background blue=low; red=high). Commercial trawl activity is shown as individual lines, colored by the trip's port of origin.



Prior to implementation in an FEP, all these methods would be tested it in a computer simulation framework to compare the performance of alternatives for the decision points in the FEP, and to identify options that are robust and would lead to good performance against objectives desired by stakeholders. This step would likely use ecosystem models such as Ecopath/Ecosim or Atlantis as operating models to represent the truth for conducting the simulations to test performance of catch advice-setting process. For some questions, simpler ecosystem models may be sufficient to address the likely ability of the advice setting process to meet goals.

9.1.1.1 Ecosystem Catch Cap

The recommended framework for providing EPU catch advice would begin by setting a total system catch cap. The rationale for a cap on total removals is to ensure only a sustainable amount of total biomass is removed. Capping total removals at sustainable levels will help to maintain ecosystem function and structure.

Several methods exist to determine the value for a system catch cap. These can include estimates based on system productivity (trophic transfer) that base limits on system dynamics that determine the total amount of energy available to higher trophic levels; i.e. harvestable fish and invertebrates (Koen-Alonso et al. 2013, Rosenberg et al. 2014). Alternatives could include results of ecosystem indicator analyses to identify system threhsolds (e.g. Large et al. 2013), production modeling (e.g. Gaichas et al. 2012), or simulation testing to determine the cap value that best allows management to satisfy objectives (e.g. Fay et al. 2013). As an example, a system for applying indicator-based thresholds is shown in Box 1.

BOX 1: Example estimation of catch cap: Large et al. (2013, 2015) and Tam et al. (2017) used survey data to identify values of total catches from ecosystems that were associated with large changes in the values for a set of ecosystem indicators. These thresholds could be used as a reference level for the total catch cap.

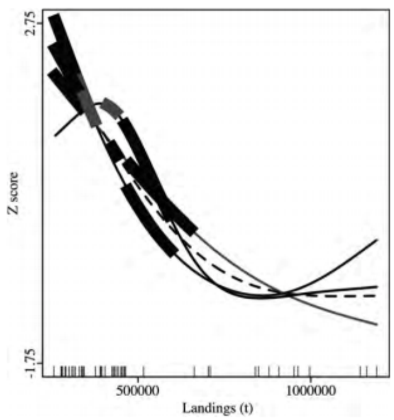


Figure 6. Centred and scaled (z-score) ecological indicators with a significant GAM (with smoothing term included) in response to landings. Rug plot represents the spread of the data, and significant derivatives are highlighted accordingly.

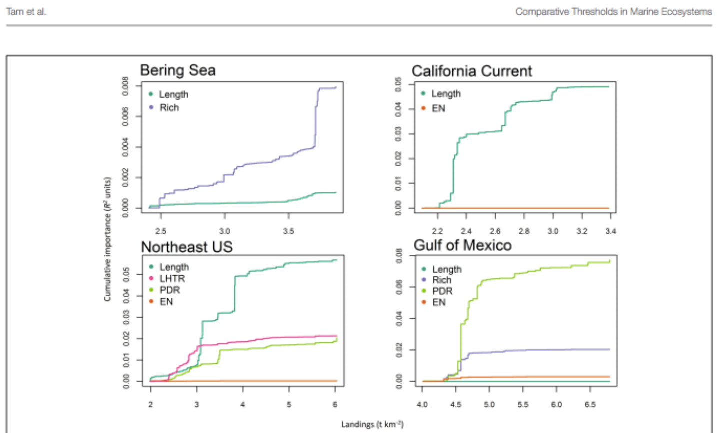


FIGURE 4 | Cumulative shifts (in R^2 units) of ecological indicator value in response to landings (t km^{-2}) from the gradient forest analyses for Alaska (Bering Sea), California Current, Northeast US, and Gulf of Mexico. Thresholds are defined as a steep increase in ecological indicator response to a pressure. Ecological indicators are mean length of catch (Length), species richness (Rich), pelagic to demersal ratio (PDR), low to high trophic ratio (LHTR), species diversity (EN).

(*Figures from Large et al. 2013, Tam et al. 2017 showing responses of ecosystem indicators to system-wide landings*)

9.1.1.2 Catch advice for stock complexes

In addition to a system catch cap for the EPU, catch advice for stock complexes would be needed to identify the maximum catch associated with overfishing, giving managers information needed to determine Allowable Biological Catch (ABC) and Annual Catch Limits (ACL). These limits would vary with the biomass of the stock complex and would apply a fishing mortality rate associated with a proxy for maximum sustainable yield from the complex. The Council would also set optimum yield that is consistent with the goals and objectives of the FEP.

- The primary catch advice will be provided at the stock complex level. Stock complexes for this process are defined as groups of species that share similar diet and habitat niches and may also have similar life-history characteristics. Stock complexes that are caught together in a particular fishery may be allocated together as a fishery functional group to a defined fishery. For example, fishery functional group specifications (ABCs) could apply to piscivores in the trawl fishery, or to benthivores in the gill net fishery, as opposed to individual species or stocks.

- The fishery functional group approach is similar to the concept of métiers employed in analysis of fisheries elsewhere in the world (e.g. Europe). Defining fishery functional groups can be achieved through a range of methods, but is likely to require engagement with managers (and stakeholders) as well as scientists to identify groups that are feasible for regulatory implementation. The eFEP contains an initial draft of stock complexes and fishery functional groups, but this will need to be refined based on the needs of the fishing, management and scientific communities.

- **Methods for estimating catch advice at the stock complex level:** This step has parallels to the stock assessment process. Thus, the approach and procedure to determine catch advice for stock complexes would mirror that process. Most likely, this would take the form of a set of population dynamics models fitted to available data for the relevant species in the complex, which could (but not necessarily) include multispecies assessment models, such as age or length-structured models (e.g. Hydra, multispecies state-space assessment model, MSVPA), or biomass dynamic production models (Kraken). These models all have single-species analogues in the current advice-setting process. As the biomass is being evaluated at the stock complex, status to reference points and definition of biological reference points would be calculated and evaluated at this aggregate group (complex) level. The total allowable catch summed across all species complexes should not exceed the overall system cap, ensuring fishery removals are limited by the productivity of the ecosystem. Examples using different methods are provided in Boxes 2, 3, and 4.

<u>BOX 2: Estimating catch advice for a stock complex based on an assessment using an aggregated production model.</u>

Application of surplus production models have a long history in assessment of fishery population dynamics in the Northeast US. These have often been for individual species. The methodology used in an aggregated production model is exactly the same as for the single-species case but the data being fit to represent a stock complex. This approach is used for assessment and management of other species groups in the US, for example for the bottomfish complex in Hawaii (Brodziak et al. 2011). The application of aggregate production models was used to set management advice on the Northeast U.S. Continental shelf during management by the International Commission for Northwest Atlantic Fisheries (ICNAF; Brown et al. 1976) before the 200-mile limit was established.

Lucey et al. (2012) fitted aggregate surplus production models to stock complexes by summing estimates of biomass (e.g. from surveys) and catch over species within complexes, and modeling the biomass dynamics at this level, to estimate MSY and BMSY reference points, and current aggregate biomass status relative to these reference points.
Catch advice for the aggregate (stock complex) level could then be derived by applying the model-estimated F_{MSY} (or the appropriate proxy level) to the estimate of current aggregate biomass.

Lucey et al.: Aggregate surplus production comparisons 225

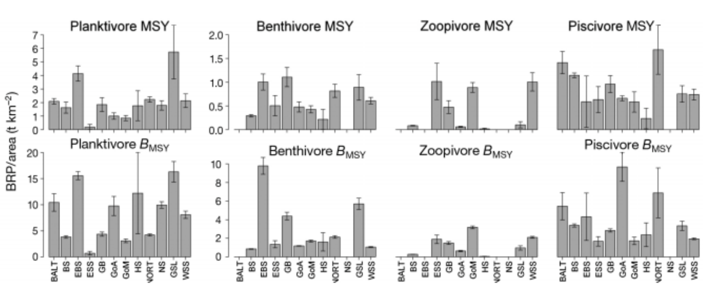


Fig. 4. Area-corrected maximum sustainable yield (MSY) and biomass at maximum sustainable yield (B_{MSY}) derived from the process error model for the feeding guild aggregation type by ecosystems. Note the different scale for the planktivore aggregate group than the other 3 aggregate groups. See Table 1 for definition of ecosystem abbreviations

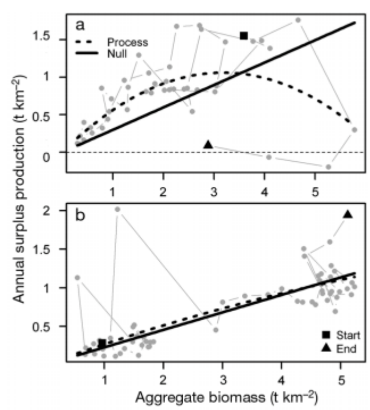


Fig. 2. Examples of the fit by the models to the data. (a) Example where the process error model (thick dashed line) fits the data well (North Sea pelagic aggregate group). This occurs for the majority of the aggregate groups across the ecosystems. (b) Example of where the null model (solid line) fits the data well (Gulf of Alaska 'large' aggregate group). This occurred in only 3 aggregate groups. The thin dashed line shows where annual surplus production equals 0

(from Lucey et al. 2012; estimates of MSY and BMSY for different stock complexes, example of aggregate production model fit)

BOX 3: Stock-complex level catch advice using a multispecies assessment model.

Aggregate production models do not account for individual species dynamics, varying species productivity, or varying availability to survey gear. Multispecies assessment models make these assumptions more explicit, by modeling the dynamics of several species simultaneously. These models are fit to data in the same way as single-species stock assessments, and the complexity spectrum of available models mimics that of single-species stock assessments. As an example, a multispecies production model was used by Gaichas et al. (2012) to define reference points for stock complexes. These reference points were based on a model with trophic interactions and interspecific competition. Multispecies production models in which interactions among species are explicitly considered has a long history in this region (e.g. Sissenwine et al. 1982; Overholtz and Tyler 1986). When appropriate data are available, advice can also account for environmental factors, such as trophic interactions, drivers of ecosystem productivity, and changes in habitat quality.

Once the models are fit, target rates of fishing mortality can be obtained from the mortality associated with maximum sustainable yield across all stocks, or some level of this based on objectives associated with low expected levels of stock collapse. This is akin to stock projections in a single-species model. After defining the target level of fishing mortality for catch calculations, the catch advice can be derived by applying this level of F to the estimate of current biomass for each species as estimated by the multispecies assessment model.

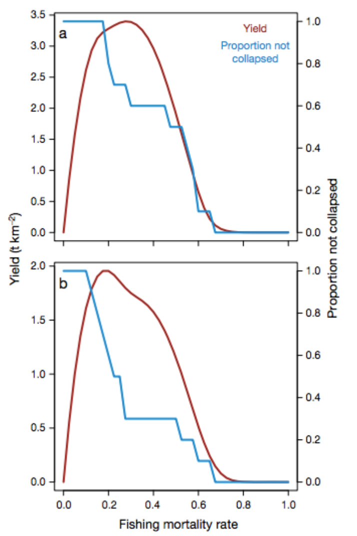


Fig. 2. Full 10-species system aggregate yield and collapse curves (where collapse is defined as biomass <10% of unfished biomass) for (a) Georges Bank and (b) Gulf of Alaska

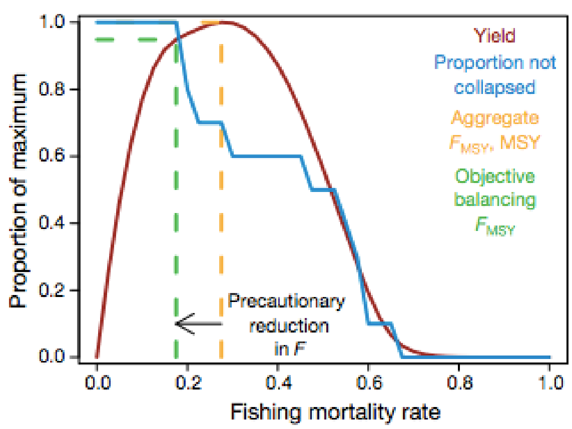


Fig. 4. In multispecies complexes, fishing mortality rate F can be reduced from aggregate F_{MSY} (MSY, maximum sustainable yield) to prevent collapses. For the full 10-species Georges Bank model, nearly 95% of MSY can be achieved with no species dropping below 10% of unfished biomass

(*example multispecies yield curves for stock complexes; from Gaichas et al. 2012*)

BOX 4: Stock complex catch advice from index-based trends method

Trends-based assessments (commonly used in 'data poor' situations) take a current estimate of a trend in a stock indicator, applying a multiplier of sustainable catch (proxy for F_{msy}) to derive advice. Such methods may or may not include explicit reference points for the stock indicator. Several stock indicators could be used but a common one is a biomass index from survey (here an index of the biomass of a stock complex). If found to be a reliable index of trend, additional indicators of stock biomass could be used or augment the survey data.

An example used in the Northeast US by the NEFMC is a survey-based 'Plan B' approach for developing catch advice for stocks that do not have accepted stock assessments (e.g. NEFSC 2015). This type of method can also be applied at the stock complex level. The method currently used fits a LOESS smooth through the spring and fall survey indices obtains an estimate of the smoothed (averaged) trend from recent years. The resulting slope of the trend scales an estimate of current catch to provide catch advice (the 'current catch' estimate is often averaged over recent years).

This approach could also be used for a stock complex by calculating the biomass indices for the stock complex (e.g. summing over species in the complex), applying a catch multiplier for the reference period to current biomass indices. The number of years over which to calculate the trend and estimate of current catch are not prescribed here, though there are several examples of this method being tested with alternative specifications for these decision points.

This approach assumes a 'complex' level biomass. Thus, it does not model single stock dynamics, and is implicit in its treatment of interactions, etc. The method could also be applied to individual stocks (as currently done) to obtain species-specific trends, and then some part of the distribution of these trends (e.g. median, or minimum) could be applied to the recent complex-level catches to derive catch advice. This approach would allow the stock complex catch advice to be more sensitive to apparent dynamics of individual species. Implementations of these approaches have shown they perform best when a reference point for the stock indicator and catch level are used (e.g. Little et al. 2008).

9.1.1.3 Matching advice and methods to FEP goals and objectives

Ultimately, the decision points for developing species complex advice would be associated with achievement of FEP goals, such as maintaining ecosystem health and balance, stabilizing the variation in catch, optimizing yield, protecting and rebuilding depleted stocks, maximizing gross or net revenue, optimizing employment and/or community resilience such that the total catch cap cannot be exceeded and that individual species are not driven below their floors. Performance indicators can be used to quantify the likelihood of achieving FEP goals. This is important as many of the proposed FEP goals and objectives are not directly considered in the assessment models and single stock catch advice.

- Portfolio analysis is one method to objectively provide catch advice subject to the constraints of the FEP goals. Apex predators and protected species are typically not part of these multispecies models because the data on them are limited, however. Output from the assessment models as well as data on apex predators and protected species could be combined in food web models such as Ecopath/Ecosim to evaluate the sustainability of catch levels across all the components of the ecosystem. This is an operational example of the approach employed in the recent Atlantic herring MSE (though this would be the operational aspect, not the simulation testing).

The output of the assessment process would be very similar to the existing single species process except the catch advice would be generated at the stock complex level, subject to a total catch cap for the ecological production unit with insurances for individual species.

9.1.1.4 Methods Glossary

1. Indicator threshold analysis: Large et al 2013 examined the observed historical responses of Northeast US Large Marine Ecosystem properties (ecosystem indicators) to a series of drivers and pressures, including fishing, to identify values for these pressures (e.g. total catch from an ecosystem) that resulted in threshold changes (tipping points) in the ecosystem properties. This method (and similar methods employed by Large and other authors) is one of many that could be leveraged to identify the value for a catch cap.

2. Ecosystem production potential: Studies show that roughly 27% of primary production (88 $gC/m^2/yr$, ~ 5.5 million mt C/y) is considered new production (microplankton) and is available to higher trophic levels on Georges Bank. The remaining primary productivity largely cycles through a microbial loop that does not contribute to the higher trophic levels. A potential appropriate limit exploitation reference point for the system as a whole therefore, could be 27% of primary productivity. To ensure that the food requirements of all the components of the ecosystem, including fish and protected species such as marine mammals, sea turtles, and sea birds are met, a target level of exploitation of two thirds to three quarters of the limiting level should be established (18-20%, ~ 3.8 million mt C/y). Primary productivity is continuously measured by satellite and the percentage of microplankton production in the EPU (27%) is calculated seasonal by multiple institutions, including the NEFSC.

3. Aggregate production models: Surplus production models are relatively simple population models that use the catch and biomass of a single stock to estimate management reference points. Aggregate production models are extensions of single species models that use the aggregate or sum of biomass and catch over a species complex instead of over just a single stock. The output produces reference points for the species complex as a whole (e.g. the aggregate stocks). The model uses the sum of the biomass and catch for the stocks within a single stock complex, but does not explicitly include interactions terms (no predation or competition). e.g. Lucey et al. (2012)

4. Multispecies assessment model- Multispecies assessment models use data from surveys and catch to estimate biomass and reference points for multiple species or multiple species complexes. They explicitly include interactions terms (e.g. predation and/or competition) among the species or complexes. Multispecies assessment models can range from simpler production models with interactions (e.g. Gaichas et al. 2012) to the more complex length/age/stage-structured assessment models (e.g. Curti et al. 2013, Gaichas et al. 2016),which are similar to the age-structured models used for many stock assessments in the region.

5. Index based catch advice – Index based methods track components of species and complexes with indicators (e.g. catch, CPUE, age-structure, survey indices, SPR). Thresholds for

appropriate/sustainable levels of the indicators are proxies for reference points. Catch advice is then set based on an evaluation of the indicator compared to the predefined threshold or reference level.e.g. Little et al. (2011), NEFSC (2015).

9.1.2 Overfished species and stocks

In defining status determination criteria (SDC) for multispecies management on Georges Bank, an FEP can extend the concepts applied to individual species/stocks under current management approaches, but in a broader, more flexible way under harvest control rules adopted to achieve FEP goals and objectives. At one level, sustainable fishing mortality rates applied to a stock complex can protect most stocks in a stock complex, but if the biomass of a stock complex becomes too low, the catch limit for a stock complex should be lower than if the ecosystem is more in balance. Nonetheless, some stocks may still become depleted or overfished due to natural variation or excess targeting of a single stock. In this case, minimum biomass thresholds based on assessments or indicators can be set to trigger stock-specific catch limits and associated measures to rebuild the biomass of that stock.

Under current management, SDCs are formulated in relation to single species Maximum Sustainable Yield (MSY) levels. Overfished status determinations are specified with respect to reference levels of biomass at MSY (B_{MSY}). MSY-based reference points used in single-species management often implicitly assume a symmetrical production function in which MSY occurs at 50% of the virgin biomass level. In this case, species are classified as overfished if they fall below one-half the B_{MSY} level (one-quarter of the unfished biomass level). For some NEFMC groundfish stocks, proxy SDCs are often employed based on defined proportions of spawning biomass per recruit. From the GARM III assessment, proxy levels for MSY were estimated by applying $F_{40\%}$ spawning biomass per recruit (SBR), with the SDC for an overfished stock being ½ of this SSB_{MSY} proxy. For many other NEFMC managed stocks, current relative biomass levels in relation to a specified historical level in available time series, such as an index from a trawl survey, are used as proxies. Currently, approximately 50% of the stocks managed by NEFMC are assessed with index-based methods using survey and/or catch data to generate proxy measures of relative biomass. These stocks currently include all the skates (7), whiting, red hake, scallops, monkfish, dogfish, two windowpane flounder stocks, wolffish, halibut, Georges Bank yellowtail flounder, Gulf of Maine winter flounder, Georges Bank cod, witch flounder, and ocean pout. The methods for determining annual biological catch (ABC) for NEFMC stocks is summarized below. Biomass is determined by either index-based methods or analytical stock assessments.

Table 3. Summary of ABC control rules used in NEFMC Fishery Management Plans

Species	ABC CR	Biomass reference point for MSY and determination of an overfished status
Large-mesh groundfish[2]	For most stocks, $F_{40\%\ MSP}$.	For most stocks, the overfished threshold is ½ of 40% maximum spawning potential (associated with SSB_{MSY}.
Herring	When biomass is greater than 0.5 of SSB/SSB_{MSY}, the maximum fishing mortality allowed is 80% of F_{MSY}. Below this biomass, fishing mortality declines linearly to zero when biomass is less than 0.1 of SSB/SSB_{MSY}.[3]	Overfished threshold is ½ of SSB_{MSY} or its proxy.[4]
Scallops	Catch associated with fishing rate that has no more than a 25% chance of exceeding OFL (including discards), defined as the estimated FMSY.	B_{MSY} estimated by analytical assessment. The stock is defined as overfished when estimated biomass is less than the B_{MSY} estimate.
Skate	Aggregate ABC for all 7 species combined; Long-term median catch/biomass ratio x 3-year avg. biomass	
Monkfish	$B_{CURRENT}$ x Avg expl. rate 1996-2006 (North) $B_{CURRENT}$ x Avg expl. rate 2000-2006 (South) CR not used in the 2017-2019 specifications based on SSC advice. SQ ABC used based on recent data. This method may be used until age validation research is complete.	
Whiting (silver and offshore hakes)	P*[1] = 25th percentile of estimated scientific uncertainty for silver hake. 4% added to southern whiting stock ABC to account for mixed catch including offshore hake	B_{MSY} proxy: Average fall survey biomass, 1973-1982. Overfished when B<1/2 B_{MSY} proxy
Red Hake	P* = 40th percentile of estimated scientific uncertainty	B_{MSY} proxy: Average spring survey biomass, 1980-2010. Overfished when B<1/2 B_{MSY} proxy
Red crab	Long-term average catch (1,775 mt determined in 2010)	OFL reference point cannot be determined – there is no biomass

[2] See Table 15 on page 86 of NEFMC 2018 for individual stock reference points.
[3] Proposed for Amendment 8, currently under review by NOAA Fisheries.
[4] Proposed for Amendment 8, currently under review by NOAA Fisheries.
[1] P* is a measure of the scientific uncertainty that an ABC is less than estimated fishing mortality that is consistent with producing MSY. P*=50% means that there is a 50/50 chance. Lower P* values are associated with less risk.

Species	ABC CR	Biomass reference point for MSY and determination of an overfished status
		proxy. However, status based on a stable 10-year history of landings is "not overfished and overfishing is not occurring"
Groundfish stocks	For most stocks with approved assessment: 75% Fmsy x B current. Other methods used for stocks with rejected assessment or other issues	

The revised National Standard One Guidelines [50 CFR 600.310(d)(2)(i)] state: "…Stocks may be grouped into complexes for various reasons, including where stocks in a multispecies fishery cannot be targeted independent of one another; where there is insufficient data to measure a stock's status relative to SDC {Status Determination Criteria}; or when it is not feasible for fishermen to distinguish individual stocks among their catch. Where practicable, the group of stocks should have a similar geographic distribution, life history characteristics, and vulnerabilities to fishing pressure such that the impact of management actions on the stocks is similar. The vulnerability of individual stocks should be considered when determining if a particular stock complex should be established or reorganized, or if a particular stock should be included in a complex...".

Of a total of 913 individual stocks of fish currently under management in U.S. waters, 658 are currently aggregated into various stock complexes for management purposes (Gamble et al. In Review). Although the motivation for management at an aggregate level is often related to data limitations or difficulties in species/stock identification, the above language in the guideline clearly recognizes the need to consider the problems in managing mixed species fisheries where targeting capabilities and species-level control on fishing mortality rates are subject to inherent limitations. There is in fact an extensive history in identification and analysis of species assemblages as management units as a way to address the effects of both technical and biological interactions (e.g Tyler et al. 1982). Under current NEFMC management, seven species of skates are treated as a stock complex as are two hake species (silver and offshore hakes of the genus *Merluccius*), due mainly to their mixing in the catch and unidentified species in the landings. There is accordingly precedent for managing aggregate groups of species in the Northeast U.S.

As a precaution against depletion of entire stock complexes and an unhealthy ecosystem structure, status determination criteria for species complexes could also follow the approach described for individual species. In this case, if the biomass of the complex as a whole falls below a threshold, remedial action would be taken as in the individual species case. The strategy of implementing remedial action at the individual species level is necessarily more conservative than similar action taken for the species complex as a whole. It could however also result in increased invocation of choke stocks in the management process.

8.3.1 Overfished SDC for Individual Species

For an assemblage of interacting species in an FEP, no single MSY level is appropriate as often assumed in single species management. Rather, any MSY-related reference points are conditioned on the abundance of interacting species. Instead, an FEP could apply a SDC derived from empirical time series a species biomass based on the best available scientific information (survey time series, assessment, minimum standardized catch per unit effort, etc.). As noted above, information from research vessel surveys are currently used as an SDC for about one half of NEFMC-managed stocks to determine whether a stock is overfished. For consistency and overall context, biomass reference points can be derived for all species using research vessel survey data as a starting point.

For species with alternative biomass estimates derived from other fishery-independent and fishery-dependent sources or other options (including catch-based methods) the best available scientific measure of biomass could be chosen by scientists and managers. For species with restricted movement patterns, biomass indices would be derived for the Georges Bank ecological production unit. Many migratory species reside on Georges Bank for only part of the year. In these cases, the biomass indices used would be derived for Northeast U.S. Continental Shelf as a whole, with catch limits applied proportionally to the Georges Bank EPU.

As an example of one possible approach, an illustration of the survey-based component of this process is shown in Figure 13. Here, NEFSC research vessel indices for 13 species on Georges Bank are shown, with a Kalman filter applied as a smoother for the mean biomass per tow. Although many alternatives for defining the floors can be identified, for simplicity, a suitable threshold (i.e. floor) is given by the lower 20th percentile of the observed survey time series as an example.

Threshold levels for individual stocks within a stock complex could also be established based on the following considerations (which area often related to its life history characteristics (Table 4).

- Vulnerability to fishing (i.e. how quickly biomass declines to excessive mortality),
- Resilience (how quickly will a stock recover when biomass below the threshold), and
- Role in the ecosystem (less risk allowed for species that play a key role, e.g. forage fish).

Higher (more conservative) thresholds could be chosen for species with high risk to overfishing. Life history traits typically identified with higher vulnerability include low fecundity, delayed maturation, larger maximum body size and slower individual growth rates. Collectively, these traits are often reflected in lower intrinsic rates of population increase. Table 4 provides metrics related to these traits for NEFMC-managed stocks.

In principle, each stock could have an individual biomass threshold for the overfished status determination. In practice, it may be desirable to identify groups of species with similar life-history characteristics and assign common thresholds within groups. Final choices of threshold values for overfished status will be made in relation to NEFMC risk policy guidelines and performance of harvest control rules relative to the metrics associated with the goals and objectives of the FEP.

Figure 13. NEFSC averaged spring and autumn research vessel surveys for 13 species on Georges Bank (closed circles 1980-2015). Lines show smoothed estimates from application of a Kalman filter for each. Portions of the time series in red indicate periods when abundance was at or below the 20th percentile for the entire series.

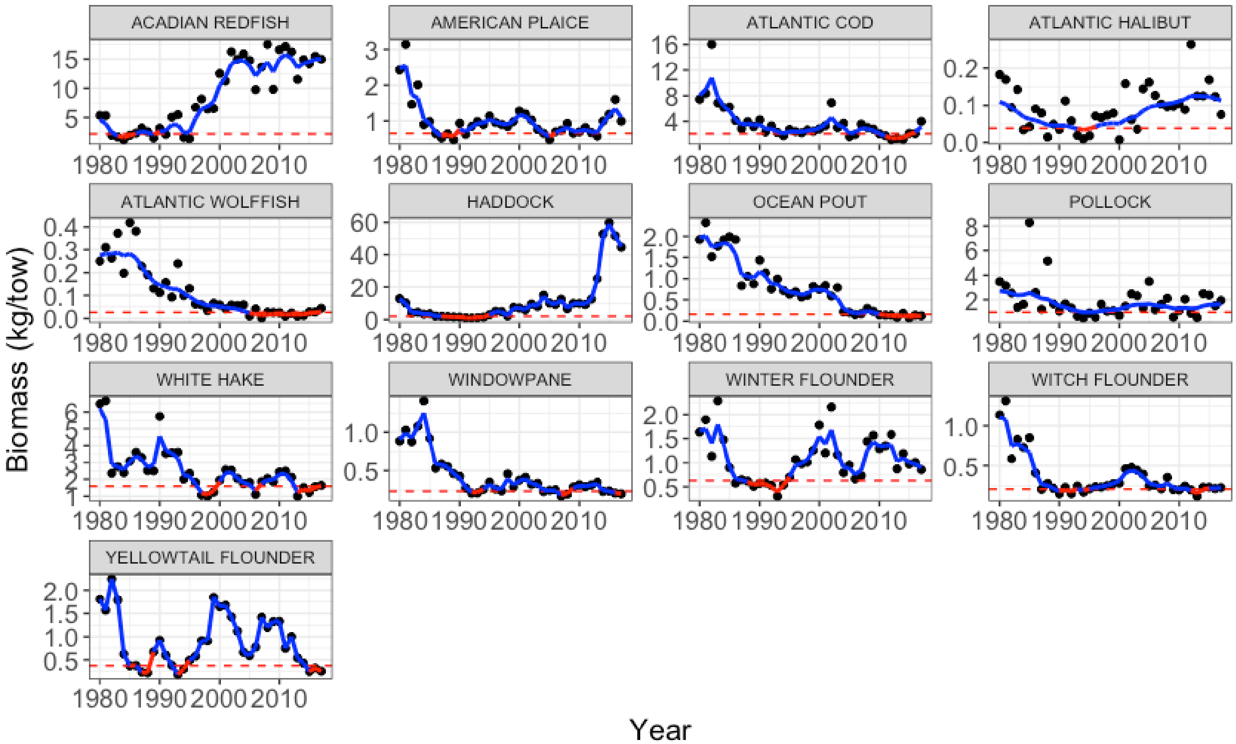


Table 4. Life history metrics and mean trophic level (TL) for species managed by the New England Fishery Management Council. Life history metrics include the intrinsic rate of increase (r), the vonBertalannfy growth coefficient (k), mean age at maturity (AgeMat, yr), longevity, and the maximum size attained (MaxSize, cm).

Species	TL	r	k	AgeMat	Longevity	MaxSize
Barndoor Skate	3.5	0.2	0.14	6.5	11	150
Clearnose Skate	4	0.2	0.15	5.5	7	94
Cod	3.79	0.66	0.115	1.8	17.5	148
Cusk	4	-		8	14	110
Goosefish	4.45	0.3	0.1	4.7	13	126
Haddock	3.67	0.51	0.29	3	9	73.8
Halibut	3.8	0.212	0.02	12	35	190
Herring	3.38	0.62	0.32	2.95	16.5	35
Little Skate	3.6	0.2	0.19	9.5	12.5	53
Ocean pout	3.11	0.12	0.095	2	18	97.8
Offshore Hake	3.42	0.9	0.174	3	14	70
Plaice	3.86	0.31	0.17	3.7	24	61
Pollock	3.72	0.88	0.14	6	24	111
Redfish	3.2	0.17	0.145	7	40	45.7
Red Hake	3.69	0.88	0.19	1.6	14	60.2
Silver Hake	3.42	0.9	0.42	2.5	14	65.4
Spiny Dogfish	3.39	0.11	0.116	17	38.6	100
Thorny Skate	4	0.2	0.12	11	16	89.5
White Hake	3.89	0.45	0.165	1.5	20	136
Windowpane	3.89	0.50	0.255	3.5	7	41
Winter Flounder	3.36	0.66	0.34	1.9	15	45.5
Winter Skate	4	0.25	0.1414	6.5	11	114.1
Witch	3.61	0.23	0.15	5.25	30	39.3
Wolfish	3.3	-	0.04	5.5	22	98
Yellowtail Flounder	3.86	0.79	0.34	2.1	17	50

8.3.2 Management Options for Overfished Species

Rebuilding strategies for overfished species could be specified based on approaches currently employed in single species/stock management. One or more of the following options can be considered. Measures that are established to promote rebuilding of one or more overfished stocks should remain in place until the its biomass reached an appropriate target, taking into consideration its role and relationship to other species in the stock complex and the ecosystem. A major objective is to reduce fishing mortality and rebuild the age-structure of depleted population in a way that will enhance prospects for successful recruitment. Recruitment of fish populations is variable and often highly episodic. Rebuilding the age composition of the stock to encompass more older individuals can increase the probability of large recruitment events. High recruitment events can be husbanded to rebuild the overall population biomass and make the transition from overfished status to a rebuilt status.

- Targeted Area Closures: Particularly for species with high habitat fidelity, areas with high concentration of an overfished stock can be identified and targeted spatial closures implemented. In contrast to other spatial measures (see Discussion Document 9 on spatial management), the use of area closures here would be intended to reduce the availability of a species to fishing. This type of rebuilding measure would be intended to enhance survival and growth, or spawning, of an overfished stock, rather than enhancing productivity for a range of stocks (as discussed as a general ecosystem management approach in Document 9). In this case, targeted area closures may also be of limited duration while stock rebuilding occurs. One of the weaknesses of this approach is that it could restrict the ability for a fishery to target healthy stocks that are found predominately within a targeted area closure.

- Effort Restrictions: Particularly for the case where several species fall below the designated threshold for overfished status, overall reductions in fishing effort can be implemented to aid the recovery of the depleted species. This can be effective, particularly when a stock complex is deemed overfished, but may also be effective if the overfished stock is the primary target of a fishery. Its weakness is that effort restrictions can be too general and prevent vessels from fishing for other stocks which are not overfished.

- Species-specific ACLs for Overfished species: Because of the mixed-species nature of many of the fisheries in the Northeast and the difficulty of exerting exact compositional control of the catch, this document includes the possibility of setting ACLs at the species complex level. One option for enhancing the prospects of recovery of overfished stocks is to set species-specific ACLs for them. Strong constraints on permissible landings levels of vulnerable species can increase the incentives to avoid catching them or to mis-report landings. Of note is that the current Sector-based groundfish quota management system is nested within this option. A strength of this approach is that it directly affects catch of an overfished species. A weakness is that it often puts the onus on industry to fish in ways that do not exceed the ACL for a stock and can be costly to monitor the catch.

- Conservation Engineering (gear technology) Solutions: Incentives to develop gear modifications to reduce the probability of capture of overfished species can be put in place. Recent examples include the haddock-separator trawl to allow capture of abundant haddock resources while affording protection to cod and other depleted species. To be effective to rebuild an overfished stock, such measures and technology need to be developed before they are actually needed for a rebuilding measure.

- Point Allocation System: Incentive structures can be put in place to encourage enhanced targeting of species in robust condition while establishing disincentives for the capture of overfished species. In the 1990s, the Northeast Seafood Coalition proposed a system in which fishers were awarded a specified number of points to spend rather than being awarded an individual quota allocation for individual species. Depleted species would require the expenditure of more points per unit weight than ‘healthy’ species, providing an incentive structure to catch and land species that are abundant while discouraging the pursuit of overfished stocks.

  A similar concept ‘ the Credit System’ has been suggested for use in EU-managed fisheries. In this case , fishing credits are equivalent to points. The allocation of points could be structured as a dynamic process, responding to changes in resource abundance over time. Unlike the above-mentioned options, there is no experience in the implementation of a points allocation scheme in the Northeast U.S. and detailed evaluation of the strengths and weaknesses of this approach would have to be undertaken. An example of a fishery credit-based system under European Union management is provided by Riell et al. (2015).

A point allocation system would need to be implemented at the outset, not just in response to an overfished status, but could allow the Council more flexibility in responding to an overfished condition by triggering an increased 'penalty' or cost for catching overfished stocks. It could also be used to increase the 'penalty' or cost for catching species that are vulnerable to overexploitation or are less resilient, relative to other stocks in a stock complex. Alternatively, stocks in a stock complex that are at high biomass levels could see a reduction in the point cost.

Current management practice specifies a time frame within which an overfished species must be rebuilt. The base period is as quickly as practicable but no more than 10 years, with the potential for extension for species with low intrinsic rates of increase or other life history traits such as delayed maturity and long life span, i.e. stocks that cannot be rebuild in 10 years or less. In principle, similar criteria could be applied in the multispecies context for species that fall below a specified biomass threshold. We note however, that delayed recovery can be due to other ecological conditions. For example, increased biomass of predators or competitors of a depleted species could impede the rate of recovery. In this case, consideration of the impact of interacting species, or changes in environmental conditions could be taken into account in specifying a recovery period in concert with life history considerations.

Currently, stock status determinations are performed on a one to five year cycle, some assessments occurring less frequently. Based on the range of available data and methods for determining stock status, it is possible to utilize a tiered approach for evaluating stocks and complexes. Based on Council and Center priorities and capacity, determining stock status at approximately three-year intervals, similar to the current scheme would likely be a reasonable approach. Annual determinations would also be possible for indicator based methods using trawl survey data on biomass and age-composition, catch and effort data and for ecosystem information such as is provided through the Ecosystem Status Report. In season changes of indicators based on catch, effort and environmental data could also be used to track ecosystem conditions and alter catch advise contingent on predefined triggers. The basic premise of this tiered approach is currently in place within the Council-GARFO system. Increased use of indicators, thresholds and predefined triggers, could track stocks and conditions and add some flexibility to respond to the current situation. Seasonal distribution shifts that are different than previous years may enable increased fishing opportunities for some stocks or create bycatch issues for others. Such approaches could enable more adaptive management.

9.2 Incentive-based measures

Incentive-based measures could provide extra conservation for some stocks and promote fishing on others, when they are part of a stock complex with other species. Some, but not all, of the problems associated with stock complex catch management will be addressed by separating species with very different life history characteristics (i.e. longevity, spawning potential, growth, etc) into different stock complexes. Other species that are part of a stock complex may be vulnerable to fishing due to higher availability and lower fishing costs, higher market value, or a higher risk due to a central role in the ecosystem and/or low resilience.

9.2.1 Introduction

The development of an appropriate incentive program for a multi-species fishery requires a good understanding of management objectives. Since there are implicit tradeoffs between common goals and objectives of fisheries management, managers can focus these objectives to help design a system which maximizes the probability of achieving the desired outcomes. Once goals and objectives identifying desired management outcomes have been developed, the management system can be designed to reinforce fishing behavior which supports these goals and objectives.

All of this occurs in a system linked through biological interactions. For example, in single species management the goal to maximize yield can compete with the goal to provide stability in catch limits through time. Similarly, maintaining employment may be in conflict with improving economic efficiency. However, fish species do not exist in isolation and thus fishing that impacts the abundance of one stock can have impacts on interacting stocks, through competition, predation, etc. The primary production of the ecosystem limits the total sustainable catch from the system, and it is impossible to concurrently catch all species at their assigned single-species MSY levels (e.g. Sissenwine 1977). Articulating an ecosystem level cap for fisheries can allow informed discussions of the trade-offs between different species, gears, and fisheries. For example, catching a forage species at its single species maximum sustainable yield could result in a lower abundance of and catch limit for predator species dependent on that species for prey. Similarly, fishing with a gear that impacts habitat will decrease the productivity of species dependent on that habitat.

Fishery management objectives are a great way to clarify stakeholder priorities for a fishery and give managers the information needed to build an appropriate incentive program. Articulating goals and objectives in clear and measurable terms provides specific targets that can be used to determine if management is meeting its goals or needs to be adjusted. They also articulate priorities such that management decisions can be made in a more transparent manner. Given that these objectives, and decisions regarding ecosystem caps, functional group management, and other foundational issues have not been finalized, the following discussion attempts to clearly define incentive based management, and provides examples of what these management systems could look like, without being prescriptive. Once management goals and objectives have been established, incentive program specifics would then be developed and tailored to align with these management priorities.

Most fishery management issues ultimately boil down to whether individual fishermen's incentives align with the goals and objectives of management, and society more broadly. Although the specifics for why individual behavior and management goals misalign can vary, market failures have long been identified as the root cause of the problem (e.g. Gordon 1954; Scott 1955).

Problem Definition and eFEP Goal

Most fishery management issues stem from a mismatch between individual fishermen's incentives (an incentive being a perceived reward for an action) and the goals and objectives of management. The goal of the NEFMC Fisheries Ecosystem Plan is to create a management system that provides fishermen with greater flexibility to choose when to fish, how to fish, and what to fish for while still incentivizing behavior aimed at achieving management objectives.

In a single-stock/single-species fishery a market failure derives from the fact that the ex-vessel price of a fish fails to account for the value of that fish if it was left in the ocean. For example, a landed fish no longer provides increased biomass or potential increase in price[5] via growth, increased recruitment via reproduction, or other benefits via biological interactions (such as serving as prey for other species). In multi-species fisheries the problem becomes more complicated, as fishermen do not have complete control over what they catch but can influence catch composition through fishing behavior/decisions such as choice of location, gear configuration, etc. (Abbott et al. 2015, Somers et al. 2018). An additional issue is the influx of effort possible most notably under open access and limited entry fisheries, which can lead to suboptimal value generated from the fishery due to over-investment in fishing technology and fleet sizes larger than optimal, as two examples. See Smith (2012) for a more exhaustive list of ways in which fisherman incentives and management objectives can misalign. The design of an incentive-based system within a multi-stock, multi-species fishery must contend with the potential for incentives to discard fish with low quotas or fish with low economic value. The extent to which these perverse incentives manifest themselves depends specifically on the difference between the net value an individual fisherman expects to derive through compliance (including the cost of compliance) and the net value derived from non-compliance (including penalties if caught in non-compliance). Incentive-based management looks to tip the scale away from non-compliance and towards compliance.

Barring the ability to monitor every action a fisherman takes, most research suggests that the best way to ensure management goals and objectives are achieved is to allow fishermen to benefit directly from behavior which supports achieving those goals and objectives. These approaches are broadly captured under the term "incentive-based management". As an example, the special access programs historically employed by the NEFMC are incentive-based management measures, as fishermen could gain access to areas otherwise closed to fishing by adopting gear designed to decrease bycatch of overfished species. The fishermen benefited directly by adopting conservation measures for overfished species, as they were allowed access to highly productive fishing grounds that they were otherwise excluded from.
Although relatively simple in concept, designing a system in which fishermen's incentives are fully aligned with management objectives is complicated, with potential for the development of perverse incentives. Further, the benefits attributed to incentive-based management hinge on transparent science and decision-making, and a system in which fishermen trust that management can achieve the stock levels being managed to. There are a multitude of management approaches that can be considered incentive-based management (see Pascoe et al. 2010). This section highlights a few incentive-based options to be considered with the NEFMC FEP, along with advantages and concerns surrounding their implementation.

5 Some species command higher ex-vessel prices for bigger fish

9.2.2 Background

Fisheries management is full of examples where fishermen's incentives do not align with fisheries management goals, creating conflict and unsustainable management. Hilborn et al. (2005) reviewed example fisheries management systems to determine characteristics shared across successful and unsuccessful management institutions. They found that the key to successful management is appropriate governance institutions that "include a reward system so that the individual welfare of fishermen, managers, and scientists is maximized by actions that contribute to a societally desirable outcome." Hillborn et al. (2011) conclude that the probability of management success is maximized with the alignment of fishermen's incentives with management goals, restrictive access, transparent (e.g. simpler) governance structures, and management implemented at ecologically and socially relevant scales. Osterblom (et al. 2011) similarly provide a general description of biologically sustainable and unsustainable fisheries management programs (Figure 14 and Figure 15). In the unsustainable program there is a negative feedback loop where inappropriate incentives lead to decreased compliance with regulations and misreporting, which erodes the quality of the stock assessment, translating into incorrect catch limits and decreased confidence in the science, which again decreases compliance, and so on in a continuous loop.

In contrast, a fisheries management program with the proper incentives can create a positive feedback loop (Figure 14 and Figure 15) with increased long-term value generated from a fishery. Accurate reporting of catches creates improved data quality, which can lead to better stock assessments and lower precautionary buffers, and increased trust in and engagement with the management system (Österblom et al. 2011). NEFMC should aim for these conditions when developing the incentive-based management for the NEFMC FEP.

Figure 14. Social=ecological feedbacks stabilizing an unfavorable European fisheries policy. In addition to the overall Evidence-Decision-Compliance feedback loop, there is also an (A) decision-overcapacity feedback, a (B) stock status-compliance feedback and a (C) evidence-decision-stock status feedback.

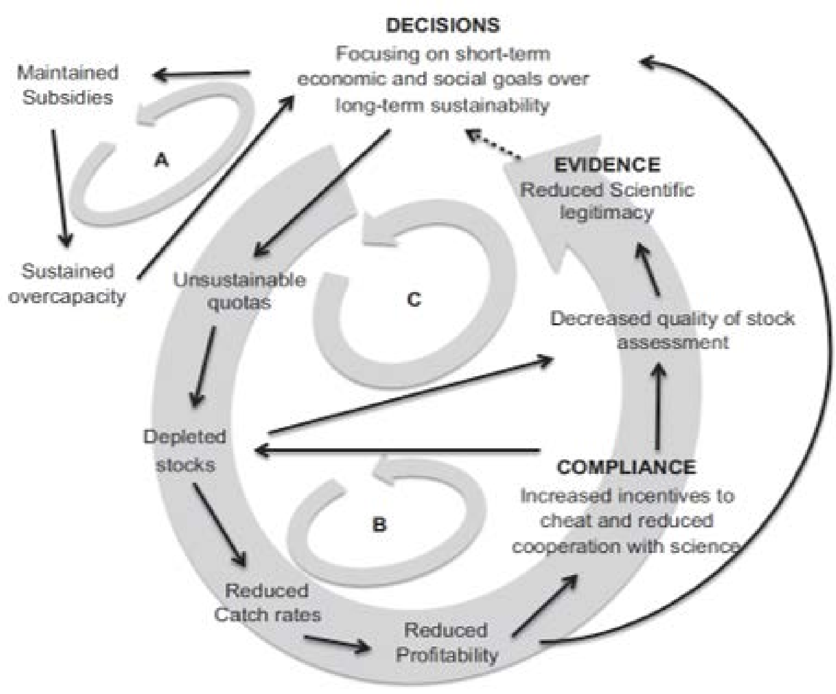
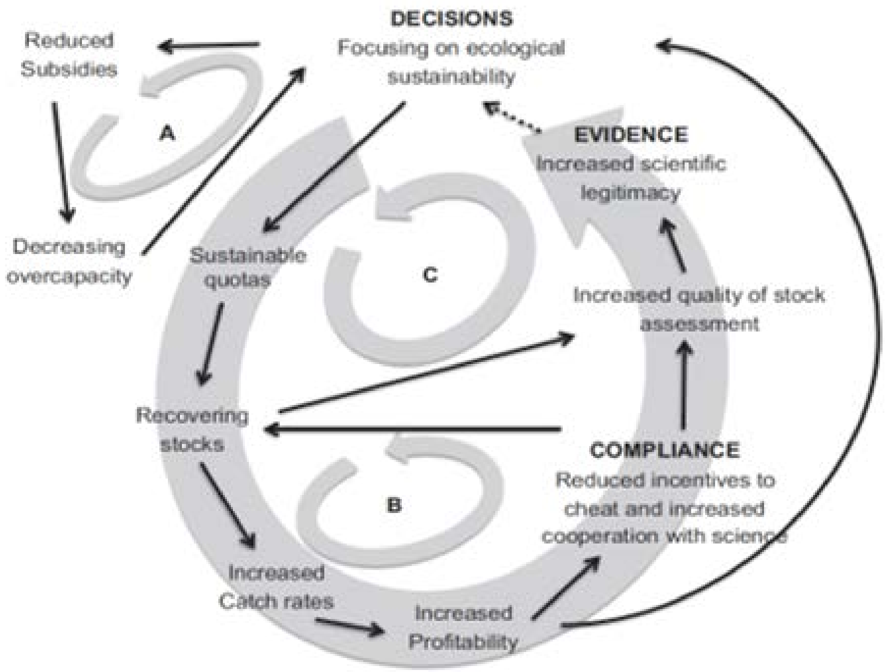


Figure 15. Social-ecological fee3dbacks stabilizing a sustainable fisheries policy (definitions for feedbacks in the above figure).



9.2.3 Incentive-based management options

Below we outline two management structures that could be used when creating a proper incentive-based program: quota based management and credit based management. Of note is that both quota and credit based management are tools that can be used in rebuilding overfished stocks, as discussed in Discussion Document 4 of this eFEP. We also provide brief descriptions of other management options that could be included as part of either of these larger management structures: bycatch reduction gear technologies, auctions to allocate quota, and shorter-term allocations of quota.

Both of the management structures outlined below could be employed at the single species level or at the stock complex level, as is under consideration in this eFEP. Stock complexes in this case would be defined as species that are caught together, play similar roles in the ecosystem with respect to the transfer of energy, and have similar life history characteristics (growth, longevity, and reproductive characteristics). The revised National Standard One Guidelines [50 CFR 600.310(d)(2)(i)] state: "…Stocks may be grouped into complexes for various reasons, including where stocks in a multispecies fishery cannot be targeted independent of one another; where there are insufficient data to measure a stock's status relative to SDC {Status Determination Criteria}; or when it is not feasible for fishermen to distinguish individual stocks among their catch..."). Of a total of 913 individual stocks of fish currently under management in U.S. Federal waters, 658 are now aggregated into various stock complexes for management purposes (Gamble et al., in review). Although the motivation for management at an aggregate level is often related to data limitations or difficulties in species/stock identification, the revised guidelines clearly recognize the need to consider the problems in managing mixed species fisheries where targeting capabilities and species-level control on fishing mortality rates are subject to inherent limitations. In the Northeast, seven skate species are currently managed as a stock complex because the landed product cannot be visually identified by species. Silver and offshore hake are also managed as a complex.

Gamble et al. (In review) simulated a range of management scenarios applied to stock complexes. These included status-quo or catch-based management; the use of indicator species within a stock complex; and management of the species complex in aggregate. In the indicator approach, management targets are derived for a selected species and these targets are applied to all species in the complex. Gamble et al. found that catch-based or status-quo management is the least likely to achieve sustainable stocks and good yield, while assessments based on an indicator species or on the aggregate complex show a great deal of promise as management tools.

9.2.3.1 Option 1 – Quota-Based Management

This approach would create individual entity (i.e., fisherman, sector, or community) based quota share fishery with stock-complex level catch limits for healthy stocks and species specific catch limits for overfished stocks. Quota shares (usually designated as a percent of the catch limit for a species/complex) are assigned to entities and used annually to calculate and allocate the privilege to catch a specific amount of fish (quota pounds for each stock or stock complex) at the start of a fishing year. Entities are allowed to sell, trade, or transfer quota shares or quota pounds in order to capitalize on differences in profitability or catch composition/selectivity across the fishery.

At their heart, quota-based incentive systems attempt to align fishermen's incentives with management objectives by providing an enforceable and long-term privilege to harvest a subcomponent of a species' biomass. These privileges can be provided either directly through quota allocated to an individual or community of fishermen, such as the current sector based management of NEFMC's Large-Mesh Multispecies fishery, or indirectly through territorial rights of fishing (e.g. Christy 1982). For the purpose of this discussion, we focus on quota allocation, including individual transferable quota (ITQ)/individual fishery quota (IFQ) and sector management, as a management alternative with respect to the eFEP and explore issues to consider while developing this type of approach. Arnason (2002) and Sanchirico et al. (2006) provide surveys of ITQ fishery management systems, including evidence for changes in fishery profitability (i.e. efficiency), changes in discarding, and increased resource stewardship. The allocation of quota at the entity level is meant to allow fishermen to benefit from the biological stewardship of the species fished, in that as a stock rebuilds the fishermen can expect their individual annual allocation to increase. This benefit from long-term stewardship of the resource can allow for a decrease in focus on short-term decision-making. The current sector system is an example of this management system.

When quota is allocated at the species level, the cost of quota increases as you get closer to the TAC, which means fishermen have an incentive to avoid the stock. If quota is allocated at the complex level, this incentive to avoid any specific stock in the complex is removed. This decoupling can be problematic if catch ratios, ex-vessel price ratios, or cost of harvest across species are not constant, which could lead to a race to fish (Squires et al. 1998, Costello & Deacon 2007).[6] These realities suggest care is needed in identifying species for aggregation, and that aggregation should consider the ex-vessel prices of species. Examples of quota managed at the stock-complex level include New Zealand flatfish and British Columbia perch and redeye (Squires et al 1998). Given that this option proposes managing healthy species at the complex-level, if needed, incentives to avoid vulnerable or high economic value species within the stock complex must be induced purely through means discussed in Discussion Document 4 of the eFEP. Decisions around the aggregation approach would impact the exact manner in which the incentives can be best aligned to meet management goals.

6 Even without the ability to target, the incentive to high-grade might still result in similar outcomes, wherein fishermen race to land the high-valued species.

Trades across individual fishermen are meant to increase flexibility in fishing by reallocating quota across fishermen depending on their need, making all participants better off than if no trade was possible. Purchase or renting of quota shares or quota pounds is the most common manner by which flexibility is built into a quota-based system. Allocations can be mismatched when the catch composition does not match the quota pounds available to a given entity. This is common as catch composition can be highly variable and is influenced by changes in the environment, changes in the abundance of predators and prey, as well as changes in fishing behavior in response to updated management measures (including the distribution of low-quota stocks). Thus, historical fishing patterns might not represent current and future plans. Flexibility[7] can be built into these systems through: interspecies trading of quota share or quota pounds[A, B, C, D], ability to carryover or use quota from one year to the next[A, B,C,D, E, F], landing fees[B], the ability to balancing quota through rental or purchase after usage[A, B, C], or allowing certain fish to be landed with no quota usage[A] (Arnason 2014; Sanchirico et al 2006). However, there can be issues with relying solely on the market to provide the necessary flexibility. For example, fishermen sometimes hold quota to buffer against uncertainty associated with catch of highly variable species with low catch limits, keeping necessary quota unavailable in the market. In the West Coast Groundfish Fishery, risk pools have developed to reduce the risk associated with an unexpected catch of stocks with low catch limits (Holland 2010; Holland & Jannot 2012; Kauer et al. 2018). More broadly, information asymmetries and transaction costs in the market can lead to a small trading volume and high variability in trade price, even within a stock on a single day, and managers can play a role in providing information to fishermen that minimizes these costs and asymmetries. See, as an example, the discussion of auctions that follows.

We note that high-grading and other forms of unobserved discarding along with illegally landing of species (i.e. mislabeling or underreporting landings) can be a concern across fisheries regardless of whether the fishery is managed by quota (Pascoe 1997), and the propensity for these practices should be accounted for within a multispecies/multistock quota system. Quota systems can incentivize discards of species with low quota (and thus high prices for quota pounds on the quota market), and can also incentivize high grading, where less valuable catch is discarded to save the quota pounds for higher value catch. Although a tradeable quota market can theoretically increase incentives to avoid bycatch and minimize misreporting (Boyce 1996), in reality this incentive depends on the level of monitoring possible[8] and penalties for non-compliance (Salvanes & Squires 1995).[9] Arnason (2014) identifies increased enforcement effort, increased penalties for non-compliance, a lowered threshold for legally establishing that non-compliance has occurred, and increasing the stigma of non-compliance through social norms as four general best practices to address issues of discarding in catch share systems. Importantly, Aranson (2014) also suggests allocation at the market category/species size can greatly help in mitigating discarding incentives, particularly with respect to high-grading. These approaches would also help address issues of illegally landing species.

The allocation of quota at the stock-complex level reinforces the need for additional catch accounting measures beyond those currently in place. In addition to the policies identified in the preceding

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7 Programs currently or historically using these processes are: A-Icelandic groundfish ITQ fishery, B-historical New Zealand Quota Management System, C-historical Nova Scotia mobile gear groundfish IFQ, D-British Columbia trawl individual vessel quota system, E- NEFMC Sector management system, F-Australia Southeast Trawl Fishery.

8 Of note is monitoring can be a function of both the fishery management body and of fishing cooperatives/communities, where self-enforcement develops from social norms.

9 Salvanes & Squires (1995) also suggest using the average firm as a yardstick with which to manage a multispecies fishery with imperfect monitoring.

paragraph, a discard ban (also known as a landings obligation or full retention program) is an alternate way in which some jurisdictions attempt to address issues surrounding high-grading and discarding and at least theoretically increase the quality of fishery-dependent catch information (see Karp et al. 2019 for a recent review). However, a discard ban by itself does not align incentives with management objectives, and thus needs to be coupled with appropriate levels of monitoring and penalties for non-compliance to be successful (Batsleer et al. 2013; Condie et al. 2013;2014; Hatcher 2014). Additionally, bioeconomic modeling has suggested that allowing some trading of the quota for the most abundant stock for the quota of the least abundant stock (Wise et al. 2015), and that setting quota based of multispecies, as opposed to single species, MSY (García et al. 2017) can help alleviate some of the issues associated with landings obligations, particularly surrounding decreases in profitability that has been consistently identified in the literature (e.g. Batsleer et al. 2016; Condie et al. 2014; Bellido et al. 2017, García et al., 2017). Potential perverse incentives include developing markets for juveniles and other undersized fish (Bellido et al. 2017), and the death of individuals in which bycatch release mortality is actually low. The perceived benefits of a discard ban must thus be weighed carefully against the costs of such a policy.

Besides the increased flexibility through trading, quota systems can provide additional flexibility by removing outdated input controls that are no longer required. For example, some gear requirements were removed after the implementation of the West Coast trawl program (see Federal Register Final rule at 83 FR 62269). Incentive-based management can also be paired with area/seasonal closures. This might be done to protect specific life history stages or vulnerable stocks, similar to the in-season spawning rolling closures currently in use.

9.2.3.2 Option 2 – Credit-Based Management

This approach would establish an individual entity (i.e., fisherman, sector, or community) credit-based fishery with species-specific credit costs of harvest, to ensure conservation of vulnerable, overfished, and both high and low economic value species. Credits are assigned to entities and used annually to calculate and allocate the privilege to catch fish at the start of a fishing year. The allocated credits can then be used to purchase the right to catch harvested species, with a pound of each species differing in credit costs depending on their abundance and economic value. Entities are allowed to sell, trade, or transfer credits.

Similar to quota-based management, credit systems look to incentivize fishermen behavior to meet specific objectives and to open opportunities for stakeholder choice as an integral and desirable characteristic of the system. In contrast to a quota-based system, in which the catch privilege is assigned at the species/stock complex level, credits are a currency that can be used to land any of a defined mix of species. The number of credits needed to catch each species differs depending on the biological status and economic value of the stock. Once an individual's allocation of points are used up, they would be obliged to either procure credits from others, either through rental or buying of licenses, or stop fishing for the remainder of the fishing year, in a similar manner to the quota-based system. The rental market for credit could function similarly to the current multispecies quota market. Also similar to a quota market, potential barriers to market trading should be given serious consideration. This is particularly true given the novelty of assessing a fair market price for credits which can be used to catch any species, and the management system can be designed to minimize barriers and facilitate trading.

An early, and innovative, example of a fisheries credit system was proposed by the Northeast Seafood Coalition in 2006 as the basis of groundfish management in the Northeast. In this case, the credit comprised an allocation of total points to individual fishers to be spent at their discretion. Individual species in the multispecies groundfishery were assigned individual points such that incentives to conserve over-exploited species (which would 'cost' more points) would be implemented and harvesting of lightly exploited species would incentivized by assigning lower point costs. The system was designed to allow ongoing updates in point pricing in response to changing resource condition, markets, and other factors. Although never implemented, the approach was tested using experimental economics in a laboratory setting and found to be promising (Anderson 2010). Simulation testing of the approach was also carried out at the UMASS School of Marine Science and Technology (Truong et al. unpublished ms) and again found to be promising. The Marine Conservation Society and Client Earth independently made a similar proposal for fisheries management under the Common Fisheries Policy of the European Union (see https://ec.europa.eu/fisheries/sites/fisheries/files/docs/body/clientearth_mcs_en.pdf).

Inherently, credit systems provide some protection from mismatches in allocation, which can for example stem from differences between historical fishing patterns and current and future optimal targeting. Credit systems can also negate the individual incentive to hold back quota as a buffer against uncertainty associated with catch of highly variable species with low catch limits, which in quota managed fisheries has been addressed by catch pools or other mechanisms.

Credit systems can be designed to meet species conservation, habitat protection, and other types of objectives. For example, Kraak et al. (2012) suggest using spatio-temporally explicit credit costs of fishing to protect critical habitat or species at critical life stages. Thus, for the same stock, a pound of catch in areas and times with known concentrations of juveniles or spawning adults would cost more in terms of credit than a pound of catch from other areas. As in Option 1, close monitoring of discarding would be required. In addition, the majority of the remaining management concerns outlined for quota-based management applies equally to credit-based systems, and can be addressed with similar approaches. Credit costs can also vary according to gear used, to help mitigate bycatch issues or habitat impacts, as examples.

An important, and challenging, requirement lies in dynamically setting the point prices for each species of interest. There can be little question that errors in setting the point prices can lead to undesirable outcomes. For example, setting the point cost of a species too low can lead to overharvesting if the error is not detected in a timely way and corrected. This general issue is of course not confined to credit/point systems. A misspecification of an ITQ species allocation can lead to similar problems. However, unlike the ITQ system which relies on accurate TAC and catch monitoring to ensure broad species conservation goals are met, a credit system necessitates accurate TAC, catch monitoring, and credit cost differential between species in order to ensure a TAC is not exceeded.

Ultimately further research is needed in understanding how incentives under a credit system differ from incentives under a quota system. In particular, the existence of lags in the management system impacts the speed at which the differential cost of landings, in terms of credit, can be adjusted throughout the year. The impact of these lags on the ability to meet conservation objectives needs to be more fully understood. Similar to Anderson (2010), experimental economics should be employed to more fully explore the ramifications of lags and other inherent constraints in the credit system on incentives to high grade and discard, and how they may differ from quota-based systems.

9.2.4 Other Options to be Considered within an Incentives Program

9.2.4.1 Bycatch Reduction Gear Technologies

The development and adoption of fishing gear/fishing practices that minimize bycatch of vulnerable and overfished stocks, as well as other ecological impacts, can also be incentivized directly in a number of ways (Pascoe et al. 2010). Similar to the special access programs historically used in New England, access to areas with concentrations of vulnerable and overfished stocks could be made conditional on the rigorous demonstration of gear and/or fishing practices that decrease bycatch of the species of interest.

The Separator and Ruhle Trawls developed to mitigate groundfish bycatch, and pingers developed to mitigate marine mammal bycatch, are two examples of gear modifications employed to decrease bycatch in New England. Beyond more selective gear development, these practices could include bycatch hotspot communication programs such as have been developed by UMass Dartmouth in the scallop fishery, for avoidance of yellowtail flounder, and herring/mackerel fisheries, for avoidance of river herring. The adoption of more selective gear/fishing practices could also be incentivized by reserving a portion of quota to be distributed to fishermen within the season who rigorously demonstrate lower bycatch levels through their fishing practices. Bycatch avoidance could also be incentivized by a greater than 1 lb quota charge for every 1 lb of fish caught in areas known to host high quantities of the species of conservation interest.

9.2.4.2 Auctions

There has been increasing interest across the U.S. in using auctions as a method to distribute access in fisheries management. Although we discuss auctions with respect to allocating quota, it is important to realize that auctions could also be used to distribute the points discussed in Option 2. Auctions can be used to distribute the initial allocation of quota share, or subsequent distribution of quota share either through redistribution of reclaimed inactive, revoked, or forfeited quota, or via a system where quota duration is limited (see the discussion on shorter-term allocation of privileges in this section). Auctions can also be used in combination with other allocation mechanisms. For example, 80% of quota could be allocated based on historical use, with 20% distributed via auctions.

One of the major limits in the use of auctions by the federal government is current MSA language which states that any revenues generated through a royalty program would be "available subject to annual appropriations."[10] Therefore, there is no guarantee that the collected royalties will be returned to that specific fishery, or even to NMFS or NOAA. However, auctions have been used to sell Research Set Aside (RSA) quota for the summer flounder, scup, black sea bass, and bluefish fisheries in the Mid-Atlantic region (Seagraves 2014). In addition, the NEFMC recently conducted an RSA program review (April 2019; https://s3.amazonaws.com/nefmc.org/8a_Final-RSA-Report_DRAFT_REVISED.pdf) which considered an auction mechanism to improve efficiency and performance of the RSA program.

Auctions can be designed to meet a number of management objectives, including providing a more transparent allocation mechanism, providing a mechanism for new entrants to enter the fishery, providing more accurate information to potential buyers regarding the economic value of the quota (which can reduce uncertainty and thereby the time and costs associated with searching for price information), collecting rent in return for the use of a public resource (as is done in the oil and gas industry), and decreasing the windfall for fishermen who receive initial quota. Drawbacks can include the cost of buying quota, which can have a disproportionate impact on small scale fishermen and potentially decreases funds available for technological innovation, and increasing management costs as a result of having to administer the auction. Auctions can be structured and designed in a myriad of ways and tailored to meet the specific management objectives of each fisheries management program. For example, they can be

10 According to the Department of Commerce Office of General Council, the only auction authority contained in the Magnusson-Stevens Fishery Conservation and Management Act appears at Section 303a(d) which deals with auctioning off allocations under a limited access privilege program to collect royalties. According to Section 303a(d)(2), "revenues generated through such a royalty program are deposited in the Limited Access System Administration Fund established by section 305(h)(5)(B) and available subject to annual appropriations."

structured to facilitate new entrants[11], provide protections for communities or smaller vessel classes, and also promote economic efficiency. Auctions should be thought of as another tool in the toolbox to help the Councils and NMFS meet their management objectives.

Providing incentives via shorter-term allocations of privileges

Extending quota for shorter-term allocations could provide a mechanism for incentivizing certain fishing behaviors. Similar to the discussion of auctions, shorter-term allocations are discussed with respect to quota, but equally apply to credit-based systems. Most existing quota programs distribute initial allocations based on some form of historical catch. MSA clarifies that the duration of the allocation cannot exceed 10 years, but most programs include automatic renewal of quota shares if they have not been revoked. There are example international programs that contain allocations that have a definitive end date. For example, Chile has a quota program where the quota is allocated for 10 years at a time (Cerda-D'Amico and Urvina-Veliz 2000), with the primary objective being transition towards economic efficiency and redistribution is through an auction. Providing a mechanism for periodic re-allocation of quota also has the potential to facilitate entry in the fishery and generates an opportunity to incentivize conservation behavior. The system could reward fishermen who have met a conservation goal (e.g., use gears that reduce bycatch, have 100% video monitoring, avoid protected resources or weak stocks, etc.) with a higher allocation of quota (or a lower auction cost for quota). For example, upon expiration of quota, any fishermen not meeting specific conservation goals (for example verifiably installing bycatch avoidance technology or video catch monitoring) would receive back 80% of their expired quota shares, and the rest would be equally distributed across the fishermen who met the conservation goals. Conversely, fishermen meeting conservation goals would receive back 100% of their original allocation, plus the redistributed share of non-compliant allocation. In this way, non-compliant fishermen historically dependent on the fishery could transition slowly from the fishery, with their allocation slowly reduced through time by choosing not to meet the conservation goals. Over time, this would result in an incremental movement of quota to fishermen with the more sustainable fishing practices.

9.3 Special priority management

9.3.1 Forage fish

9.3.1.1 Fishery Ecosystem Plan Preferred Approach

Due to their special role in the ecosystem, supporting the productivity of higher trophic level species, the harvest control rules for stock complexes that include forage species and the catch limits derived from them may have different reference points than those other managed species. Such control rules might reduce ecological risk of depletion of important forage and possibly boost productivity.

Harvest control rules in an ecosystem plan could however develop from a holistic approach to set catch limits to achieve the plan's overall goals and objectives, which could include maintaining healthy and abundant populations of forage fish as a buffer against risk. The Council's existing risk policy includes the following and could be included in a fishery ecosystem plan:

> *"(C) The benefits of protection afforded to marine ecosystems are those resulting from maintaining viable populations (including those of unexploited species), maintaining adequate forage for all components of the ecosystem, maintaining evolutionary and*

11 Auctions can be developed that restrict who can bid on what as well as providing bidding credits to groups such as small boat operators, community permit bank entities, new entrants, etc. Please note there are other management tools that can also accomplish this and auctions are just one tool in the toolbox.

> *ecological processes (e.g., disturbance regimes, hydrological processes, nutrient cycles), maintaining the evolutionary potential of species and ecosystems, and accommodating human use."*

In this way, the type of harvest control rules for forage fish in one or more stock complexes would develop out of management strategy evaluation, rather than as a specific forage fish management policy. By accounting for the energetics of the ecosystem in harvest control rules, management of forage fish should be an outcome of strategies that achieve FEP objectives. The Georges Bank EPU is unlike many upwelling driven systems, where a dominant forage species are a key factor in supporting upper trophic level fish. Predators on Georges Bank tend to switch prey species more often, depending on availability of prey, although there are some obligate feeders such as certain species of birds. It would be appropriate to limit the amount of removals from the total forage base, recognizing the diverse and more robust characteristics of this system. Also for this reason, the Council believes that eggs, larvae, and juvenile fish should be accounted for in the forage base. For some species, these life stages are important prey items. For example, herring eggs have been an important food source for supporting cod populations.

Optimal management of forage fish ultimately depends on the trade-off between their indirect in situ value versus their direct market value. This trade-off is often complicated, and differs wildly from species to species. For example, Atlantic herring (*Clupea harengus*) serve as an important prey species for many animals, including commercially valuable fish such as Atlantic cod and certain species of tuna, recreationally valuable species such as striped bass, and protected species including harbor porpoise and grey seals, to name but a few. Conversely, Atlantic herring serves as the primary bait for the highly valuable American lobster fishery. Managing these trade-offs necessitates deep knowledge of not only the species ecology, but also the uses of and substitutes for these species within the economy. Further these tradeoff choices are based not just on ecological preferences and commercial uses, but cultural and social preferences as well. Some societal preferences may favor forage fish in situ not only for their forage value within the ecosystem but also, for instance, because large schools of forage fish close to the coast can attract marine mammals that people like to view from the beach or whale watch vessels. In a different example favoring extraction, herring, was once a major food fish in the US and still is elsewhere. While US preferences for herring as food have declined (there were once 17 herring canneries in Maine, but only one is left), that trend may be changing. Some upscale restaurants along the east coast have begun serving fresh herring, for instance. Additionally, many 'eat local' and 'slow food' movements promote eating whatever is off your coast and starting as low on the food chain as you can. Such movements have been gaining adherents (Olson et al. 2014). Different communities within New England will be more and less dependent on forage species for harvest and sale and/or as supports for other species they target that predate on forage species or for the tourism value of the marine mammals they attract. Further, global markets can also change based on changing social preferences in nations that might import our forage fish. Given adequate information on all of these fronts, optimal harvest levels can be derived from bio-socio-economic multispecies models. See Charles (1989) for a theoretical exposition of how these types of models can be operationalized. However, the state of the science is such that these models have yet to be practical.

Barring full bio-socio-economic models, population dynamics, ecology, economics, anthropology, sociology and other social sciences can help generate an understanding of the relative trade-offs between these direct and indirect benefits through an understanding of the economic, social, and ecological dependence on the forage fish of interest. Economically, this can be achieved by first developing an understanding of valuable species that predate on, and the preferential targeting of, the forage fish of interest. This helps to ascertain not only which species are likely to benefit from alternative management strategies, but also identify which strategies are likely to generate the benefits of interest.

9.3.1.2 Definition of forage

"Forage fish" is generally a well-understood concept that is difficult to define in precise terms. Instinctively, fishermen understand the term to mean species of fish that provide important amounts of nutrition to predators. Ecosystems with different characteristics will have a different suite of forage fish which can have different characteristics. Species that serve as important forage in an upwelling system are likely to be different than in a non-upwelling system, tropical ecosystems also being different from temperate ecosystems. Predators in non-upwelling and/or tropical ecosystems will generally rely on a more diverse mix of forage species and prey switching occurs.

At the 1996 Lowell Wakefield Fisheries Symposium on Forage Fishes in Marine Ecosystems Symposium, Springer and Speckman (1997) concluded that "forage fish is a concept that many people have come to understand because of the context it is used in, but for which we lack a concrete definition. The term embodies a peculiar combination of ambiguity and precision." In a Fisheries essay, Rountos (2015) reported that, "we still lack a common operational definition used among scientists, industry, policy makers, and the public." and carried out a literature search using FishBase (Froese and Pauly 2015) and other sources to identify common life-history characteristics and roles as prey in marine ecosystems. Commonalities included small size (<30 cm), short lifespan (1-3 years), and occupy an intermediate trophic level. Rountos (2015) also found that from a scientific point of view, forage species should also include key invertebrates (e.g. euphausiids, cephalopods, and shrimp). He found that the trophic levels of fish deemed to be a forage species had a median value of 3.2 (range 2.1 to 4.5), but increased to 3.6 when juvenile fish are included in the forage base.

For their Ecosystem Approach to Fishery Management (EAFM) policy, the MAFMC more recently adopted the following definition of forage as a species that:

- Is small to moderate in size (average length of ~5-25 cm) throughout its lifespan, especially including adult stages;
- Is subject to extensive predation by other fishes, marine mammals, and birds throughout its lifespan;
- Comprises a considerable portion of the diet of other predators in the ecosystem in which it resides throughout its lifespan (usually >5% diet composition for > 5 yrs.);
- Has or is strongly suspected to have mortality with a major element due to consumptive removals;
- Is typically a lower to mid trophic level (TL) species; itself consumes food usually no higher than TL 2-2.5 (typically zooplankton and or small benthic invertebrates);
- Has a high number of trophic linkages as predator and prey; serves as an important (as measurable by several methods) conduit of energy/biomass flow from lower to upper TL;
- Often exhibits notable (pelagic) schooling behavior;
- Often exhibits high variation in inter-annual recruitments; and
- Relative to primary production and primary producers, has a ratio of production and biomass, respectively, to those producers not smaller than on the order of 10^{-3} to 10^{-4}

Forage fish are generally small to intermediate-sized species, occurring in schools or dense aggregations, and function as a main pathway for energy to flow from phyto- and zooplankton to higher trophic level predators, such as tuna, Alaska pollock, and other wildlife, in marine ecosystems. While most species function as prey of others at some life stage, especially when small and young, forage fish maintain this important trophic role throughout their life. Further, fluctuations in their populations can result in significant changes in marine communities and ecosystems. Therefore, particular attention to management of forage fish species, and addressing their unique role in marine ecosystems, is critical to maintaining ecosystem function and sustainable fisheries.'

A House of Representatives bill (HR 2236), the Forage Fish Conservation Bill, is in committee and Section 4 of the bill would include a definition of forage. The Councils are considering how this draft bill would affect fisheries and their management plans.

9.3.1.3 Current measures and policy

In addition to direct management of forage fish [Atlantic herring (NEFMC); squid (MAFMC), menhaden (ASMFC), and Atlantic mackerel(MAFMC)], there are implicit and explicit management policies that have been established by the NEFMC and MAFMC for unmanaged or ecosystem component species, The NEFMC includes the following statement in its Risk Policy

> *"(C) The benefits of protection afforded to marine ecosystems are those resulting from maintaining viable populations (including those of unexploited species), maintaining adequate forage for all components of the ecosystem, maintaining evolutionary and ecological processes (e.g., disturbance regimes, hydrological processes, nutrient cycles), maintaining the evolutionary potential of species and ecosystems, and accommodating human use."*

The MAFMC has approved an unmanaged forage fish plan which limits landings in the Mid-Atlantic region for a variety of unmanaged species.

In the NEFMC regulated mesh areas, vessels cannot use small-mesh fishing gear (which may otherwise be used to target forage species) unless through a special Exemption Area program. Although originally intended to minimize mortality on juvenile groundfish, the regulated mesh area policies effectively eliminate the ability to target forage fish unless specifically allowed.

These regulated mesh areas prohibited the use of small mesh unless such fishing were specifically allowed via an exempted area. These exemptions define what type of fishing may take place, open seasons, and amounts that may be retained by species. If the species possession limit was not specifically listed for the exemption (e.g. herring, squid, monkfish, lobster, whiting, etc.), retention is prohibited.

9.3.1.4 Background

Globally, there is a clear increase in the sensitivity of managers to the need for ecosystem-based approaches to fisheries management, with forage species and fisheries playing a prominent role (e.g., Smith et al. 2011). Current US fishery management legislation defines optimum yield from a fishery as that which will "provide the greatest overall benefit to the Nation, particularly with respect to food production and recreational opportunities, and taking into account the protection of marine ecosystems." Given the multiple ecosystem services provided by forage species, a fuller consideration of economic and ecosystem tradeoffs, as well as forage species life history and societal preferences, is likely required to meet objectives for all managed and protected species within an ecosystem, as well as humans.

US Fishery Management Councils must include measures in FMPs to conserve both target and non-target species and habitats, considering ecological factors that affect fishery populations (16 U.S.C. 1853 § (c)(12)). The National Standard Guidelines Final Rule for NS1 recognize the special status of forage fishes and the need for precaution, stating, "In addition, consideration should be given to managing forage stocks for higher biomass than B_{msy} to enhance and protect the marine ecosystem." ((50 C.F.R. § 600.310). There are several forage species management approaches that have been proposed generally, and others which have been applied in other US regions which may be relevant to Mid-Atlantic forage species management. These approaches differentiate forage species which are already exploited by fisheries from those that are not subject to directed fishing (“non-target” species).

Exploited forage fishes generally are managed in an approach similar to other fish stocks, with a degree of precaution added in recent decades to acknowledge their key role in ecosystems. Quota-based, single-species management, based on age-structured assessment models and F_{msy}, B_{msy} reference points (or proxies) are the typical management approach (Barange et al. 2009). The Lenfest Task Force (Pikitch et al. 2012) proposed reference points that are scaled to level of confidence in scientific knowledge and assessment reliability, with lowest F and highest B reference points associated with stocks that are the most data-poor. Summary recommendations for forage fish management indicate that $F < M$, probably considerably less, and $F < F_{msy}$ should be adopted as reference points for forage fisheries while maintaining B well above the 40-50% B_0 that is conventionally specified as B_{msy}. In a few well-assessed forage stocks, minimum biomass thresholds have been used as reference points to terminate fishing to protect these stocks when recruitment conditions are likely poor, the population is low, and maintenance of predator productivity is threatened (e.g., Barents Sea capelin, California sardine).

The recommendations for appropriate F and B reference levels in targeted forage fisheries, even when precautionary, typically do not directly consider predator demand and its inter-annual variability. It has been proposed that F in forage fisheries should scale to predator demand (e.g., Collie and Gislason 2001) since M2 (predation mortality) varies substantially from year to year, scaling to predator abundances. In this approach, if total mortality is held constant, then F will vary inversely with M, rising when predator demand is low and falling when predator demand is high. Annual landings also are likely to vary substantially under this management approach, which may be undesirable from an economic, and more broadly social, standpoint.

All of these augmented targets induce costs as well as benefits, and assessing both sides of the equation is paramount in making sound policy decisions. Ultimately, the appropriateness of any target will depend on the management objectives, and will vary with the species under consideration. Setting aside scientific uncertainty regarding estimating the appropriate stock levels, the ability of precautionary management to translate additional biomass into realized management goals ultimately depends on the exact role each forage fish species plays in the environment. For example, enhancing productivity of specialist predators through enhanced availability of preferred prey is likely a more attainable goal than enhancing the productivity of an opportunistic predator by enhancing the availability of a sub-set of forage species they predate on. This is particularly true given that, as defined, the four forage fish under MAFMC management make up a small fraction of the total forage assemblage of importance to the NEUS LME, both in terms of diet frequency and total species number (see table 5).

Moratoria on development of new forage species fisheries have been proposed or enacted throughout the US. In U.S. waters of the North Pacific and Bering Sea, fisheries on many forage species are not allowed by the North Pacific Fishery Management Council (NPFMC). Considering unfished and unmanaged forage fishes, the Pacific Fishery Management Council (PFMC) and its Ecosystem Workgroup have developed policy on a diverse assemblage of unfished forage species, with an eye to their conservation and insurance that they are not targets for new fisheries without rigorous assessment, evaluation, and deliberation by the Council (PFMC 2014). Targeted forage species already are included in the PFMC Coastal Pelagic Species FMP (sardine, anchovy, jack mackerel), which also includes krill as a prohibited species. The PFMC’s Ecosystem Workgroup has proposed to include a complex of unfished forage species in each of its four FMPs as Ecosystem Component species, recognizing their value as forage for managed, targeted species and as a caution against uncontrolled development of fisheries on a diverse group of poorly known pelagic and mesopelagic species.

In the New England region the Atlantic herring and Atlantic menhaden are by definition typical forage species, and their fisheries are managed with designated ABCs and effort controls based on biomass and fishing mortality reference points commonly applied in single-species management. At present, Atlantic herring has good status relative to these reference points. Other forage species like the sand lance are not currently fished or managed, but do play a role in supporting production of managed fish and other predators in the ecosystem. In the next section, we describe potential alternative management measures for currently fished and unfished New England forage species.

9.3.1.5 Ecosystem services and forage species

Collectively, forage species provide an important supporting ecosystem service. The primary ecological role of forage species is energy transfer; these relatively small fish and invertebrates (e.g., squids and krill) tend to be central in food webs. They eat very small prey (zooplankton or small benthic invertebrates), and are themselves eaten by larger animals in the ecosystem, including the predatory fish often targeted in commercial fisheries, as well as marine mammals, seabirds, and other protected species. Forage species tend to be highly productive relative to larger predatory fish, marine mammals, and birds. These characteristics can be used to formally define forage species. During recent MSA reauthorization discussions, the following forage fish definition was proposed: "The term 'forage fish' means any low trophic level fish that contributes significantly to the diets of other fish and that retains a significant role in energy transfer from lower to higher trophic levels throughout its life cycle.'' Fishery scientists and managers therefore recognize this key role of forage species in fueling production of valuable predator fishes (Smith et al. 2011). But, the broader role of forage species in sustaining productivity and structure of marine ecosystems is less understood or appreciated (Engelhard et al. 2014).

Fisheries for forage species represent an important ecosystem provisioning service. Globally, forage species are major contributors to marine fisheries, constituting >35% of annual landings in recent decades. The dockside value of global forage species landings was $5.6 billion in 2009 (Pikitch et al. 2012, 2014). Most of these landings are converted to meal and oil, and used as feeds in livestock and aquaculture industries, or used as bait. These linkages between industries demonstrate forage species economic as well as ecological support roles. In the Mid-Atlantic region, forage species, especially the Atlantic menhaden, are key contributors to the quantity and value of regional fisheries landings, in addition to their value as prey for diverse predators. Annual combined Mid-Atlantic and New England landings of targeted forage species exceeded 210,000 metric tons in 2008-2012.

While the landed value of forage fish is high, the global value of the forage fish supporting the production of marine commercial predator fishes was estimated to be even higher at $11.3 billion (Pikitch et al. 2012, 2014). This highlights the importance of managing forage species for both sustained production of managed piscivorous fish and for direct fishery removals. Additional management considerations extend to unfished protected species such as seabirds. In a recent review and analysis, Cury et al. (2011) found that seabird populations were especially sensitive to declines in forage fish biomass, with seabird reproductive failure often associated with declines in forage biomasses to <33% of the forage species' unfished biomass (B0). However, since successful seabird fledging requires forage to be available near breeding colonies during breeding season (Elliot et al 2009, Bertrand et al 2012); where and when fishing occurs is as important as how much if management objectives include sustaining seabird reproductive success.

Forage species life history is also important to consider for effective management. These species tend to be highly productive and short-lived, with only a few age classes represented in a population. Some can also exhibit population "boom and bust" cycles. Historically, shoaling pelagic forage fishes were considered to be relatively insensitive to fishing, although extreme abundance fluctuations were observed.

Climate drivers have a strong role in controlling what sometimes has been called "the forage fish rollercoaster" (Dickey-Collas et al. 2014). For example, the Peru anchoveta population waxes and wanes in response to El Niño conditions in the Humboldt Current (Barange et al. 2009). Decadal-scale variability in abundance of major forage fish is often associated with ocean regime shifts that signal shifts in ecosystem productivity (Alheit et al. 2009). In recent decades, it has become increasingly apparent that intense fishing can deplete forage species as commonly as other types of fishes (Beverton 1990; Patterson 1992; Pinsky et al. 2011). When environmental conditions are unfavorable for reproduction and recruitment, fishing such stocks at high levels of exploitation increases the possibility of stock collapse (Murphy 1967, 1977; Pinsky et al. 2011). Forage species exhibiting strong shoaling behavior can have increased vulnerability to fishing in years of low abundance because schools remain easy to locate. Fishery catch-per-unit effort may not decline at low stock abundance, leading to excessive optimism about stock status and a high risk of stock collapse if CPUE is the only information used to assess stocks (Csirke 1988).

9.3.2 Landings prohibition (e.g. thorny skate, smooth skate, Atlantic salmon, etc.)

At times it may be necessary to prohibit landings of a species that is in dire need of protection. This may be a species that has low resilience to being overfished and cannot rebuild without prohibiting possession. It may also apply to a species that is officially considered to be endangered or threatened. Under any of these conditions, the stock biomass is generally so low that it does not appreciably contribute to the total biomass for a stock complex to which it would otherwise belong. Objectives of an FEP however may include those that protect and maximize rebuilding of extremely depleted populations. Therefore consideration of the effects of prey and predators of these species should be taken into account for evaluation of stock complex harvest control rules and annual catch limits.

9.3.3 Area or gear restrictions

Many of the existing management measures, such as area closures and gear restrictions, would continue in some form to improve size or species selectivity, protect spawning, and/or make gears less impactful on sensitive and/or critical habitat, and on protected species. This FEP is not intended to replace the habitat protection areas that were established by the Omnibus Habitat Amendment 2, except that such area restrictions would be evaluated for their effects on the ecosystem productivity and could be modified accordingly at some future date. Spatial management approaches are discussed in more detail in Section 9.4.

9.4 Jurisdictional authority, cooperation and coordination

In contrast to managing stocks in separate FMPs, the general concept of EBFM is to account for biological and technical interactions between species that are caught by commercial and recreational fisheries in a wholistic way to achieve common goals and objectives (instead of single-stock MSY). It also embodies a space-based approach where all fisheries in a defined area are managed consistently.

Out of 74 species that are commonly caught in the Georges Bank EPU by commercial and recreational fisheries, only 26 are managed solely by the NEFMC (Table 4). Twenty-two (22) are managed by other management authorities and 20 are unmanaged. Six species are jointly managed by two or more authorities and in some cases, states also manage how fishing occurs through size limits and state quotas.

In terms of commercial landings, however, NEFMC-managed stocks account for 63-66% of the total finfish landings[12] in 2018 (Table 5), depending on how the data are analyzed[13]. Stocks that the NEFMC managed jointly with another authority (MAFMC or ASMFC) account for an additional 21-25% of finfish landings. The proportion of catch, however, may be somewhat different than the proportion of landings, especially when unmanaged (and often lower value) species are taken into account. Recreational fisheries in the Georges Bank EPU are not as important as they are in other areas closer to the coastline, but they tend to focus more on species managed by the MAFMC and HMS. Therefore, the fraction of catch by commercial and recreational fisheries is more balanced toward species managed by other authorities than the fraction based on commercial landings alone.

[12] Scallops, clams, and lobsters were excluded from this analysis because it is likely that these species are unlikely to be included in stock complex harvest control rules, but the fisheries may however be included in FEP management due to technical interactions, i.e. bycatch and habitat effects.
[13] Dealer reported landings are assigned to statistical areas by VTR match and by an algorithm for trips without matching VTR data, but are complete. Analysis of the fishing location using VTR data is more precise, but some trips lack location data and the VTR data alone do not account for all landings.

Table 5. Management authority for Georges Bank EPU species that are commonly landed or caught by commercial and recreational fisheries.

NEFMC	MAFMC	ASMFC	Jointly managed stocks	NMFS-SFD	Unmanaged
Acadian Redfish	Atlantic Mackerel	Alewife	**NEFMC/ASMFC**	Bluefin Tuna	Blackbelly Rosefish
American Plaice	Bluefish	American Lobster	Atlantic Herring	Swordfish	Blue Crab
Atlantic Cod	Butterfish	Atlantic Menhaden		Yellowfin Tuna	Cancer Crabs
Atlantic Halibut	Golden Tilefish	American Shad	**NEFMC/MAFMC**		Chain Dogfish
Atlantic Wolffish	Longfin Squid	Blueback Herring	Monkfish		Channel Whelk
Barndoor Skate	Ocean Quahog	Jonah Crab			Conchs
Clearnose Skate	Shortfin squid	Other Skarks	**MAFMC/ASMFC**		Cunner
Haddock	Surf clam	Smooth Dogfish	Black Sea Bass		Cusk
Little Skate		Striped Bass	Scup		Fourspot Flounder
Longhorn Sculpin		Tautog	Summer Flounder		John Dory
Ocean Pout		Weakfish			Lady Crab
Offshore Hake			**MAFMC/NEFMC**		Lumpfish
Pollock			Spiny Dogfish		Mussels
Red Crab					Northern Searobin
Red Hake					Octopus
Rosette Skate					Sea Cucumber
Sea Scallop					Sea Raven
Silver Hake					Sea Urchin
Smooth Skate					Spider Crab
Thorny Skate					Striped Searobin
White Hake					
Windowpane					
Winter Flounder					
Winter Skate					
Witch Flounder					
Yellowtail Flounder					

To help characterize the issue and potential effects, the table below summarizes the number of permits and landings for vessels fishing in the Georges Bank EPU during 2018 by management authority. The table below sums the number of issued permits (zeros indicate that the vessel was issued only a NEFMC or MAFMC open access permit. Although the table summarizes only fish landings (excluding scallops, clams, crabs, and lobster), the limited access permits include scallop limited access and lobster permits.

In each column, the number of MAFMC limited access permit types (ranging from 0 to 7) per vessel is summarized. Joint plans (i.e. monkfish and dogfish) unfortunately make this summary more complex. On the left side of the table, the number of vessels, trips, and landings are summarize for vessels that in 2018 held neither a joint monkfish or a dogfish permit. The right side of the table includes vessels, trips, and landings by vessels that held either a joint monkfish or dogfish permit (or both).

The numbers in the first column (0 to 4) indicate the number of NEFMC limited access permit types held by a vessel fishing in the Georges Bank EPU during 2018. Thus it does not include vessels with issued limited access permits that did not fish during 2018 or that fished elsewhere.

As a brief explanation of how to read and interpret the table, there were 767 vessels that landed fish caught in the Georges Bank EPU (approximated by statistical areas) in 2018. Of these, 261 held either a joint monkfish or dogfish permit and 506 held neither. Only 5 vessels (3+1+1) had a MAFMC limited access permit but did not have a NEFMC limited access permit. However, there were 151 vessels (340+36-225 open access only permits) that held a NEFMC limited access permit, but not a MAFMC permit. For landings, 13,944 mt (63%) were NEFMC-managed stocks, 1,091 mt (5%) were MAFMC-managed stocks, 5,573 mt (25%) were jointly managed, 211 mt (0%) were ASMFC-managed stocks, and 1,346 mt (6%) were unmanaged stocks. Of these totals, only 27 mt of NEFMC stocks were landed by vessels without a NEFMC limited access permit, only 1 mt by vessels having a MAFMC limited access permit (but no NEFMC limited access permit). On the other hand, there were 23 mt of MAFMC-managed stocks by vessels without a MAFMC limited access permit, and only 14 mt by vessels holding a NEFMC limited access permit (but not a MAFMC permit).

Table 6. Comparison of permits issued and commercial landings by Council for vessels fishing on Georges Bank (statistical areas 521, 522, 525, 526, 561, 562) during 2018.

	No monkfish or dogfish permit									Monkfish or Dogfish permit										
	MAFM																			
	No monkfish or dogfish permit								No monk	Monkfish or Dogfish permit								Monkfish	Grand Total	
NEFMC permits	0	1	2	3	4	5	6	7		0	1	2	3	4	5	6	7			
Permits																				
0	225	3	1						229			1						1	230	
1	98	36	17	12	3	10	2	2	180	20	36	9	6	1	9	7		88	268	
2	16	26	5	21	2	5	6	7	88	14	53	10	8	8	19	10	14	136	224	
3	1	1		1		1	1	4	9	2	11	1	2	1	7	6	2	32	41	
4												1					3	4	4	
VTR trip reports																				
0	1,164	12	0						1,176			1						1	1,177	
1	1,908	274	96	177	81	91	34	15	2,676	914	227	391	65	14	83	117		1,811	4,487	
2	90	151	27	109	35	44	34	47	537	236	532	65	50	156	165	106	145	1,455	1,992	
3	3	8		2		4	0	21	38	15	70	33	5	2	38	58	7	228	266	
4												7					19	26	26	
NEFMC fish landings,mt																				
0	26	1	0						27			0						0	27	
1	432	1	0	262	12	242	303	0	1,253	3,404	113	938	341	60	286	909		6,051	7,304	
2	0	1	0	0	0	0	85	1	87	1,151	1,675	141	8	1,075	658	809	296	5,813	5,900	
3	0	0		0		0	0	0	0	0	35	390	0	0	2	287	0	713	713	
4												0					1	1	1	
MAFMC fish landings, mt																				
0	9	0	0						9			0						0	9	
1	14	754	0	1	8	5	9	10	799	0	0	0	0	0	1	7		8	807	
2	0	246	0	3	0	0	1	4	254	0	1	0	0	0	1	5	6	13	267	
3	0	0		0		0	0	0	0	0	0	0	0	0	6	2	0	8	8	
4												0					0	0	0	
Joint NEFMC/MAFMC landings, mt																				
0	1,592	0	0						1,592			0						0	1,592	
1	297	14	9	72	0	8	2	0	403	931	128	325	76	55	198	8		1,721	2,123	
2	24	42	0	10	0	8	3	4	91	391	380	150	10	96	279	114	57	1,477	1,567	
3	6	0		0		0	0	3	9	8	60	164	0	0	30	15	0	277	286	
4												3					2	5	5	
ASFMC fish landings, mt																				
0	190	0	0						190			0						0	190	
1	2	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0		0	2	
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
3	0	0		0		0	18	0	18	0	0	0	0	0	0	0	0	0	18	
4												0					0	0	0	
HMS fish landings, mt																				
0	25	0	0						25			0						0	25	
1	11	1	1	2	0	0	0	0	15	0	0	0	0	0	0	0		0	15	
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
3	0	0		0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	
4												0					0	0	0	
Unmanaged fish landings, mt																				
0	687	0	0						687			0						0	687	
1	2	39	0	0	0	0	24	411	476	0	1	0	0	0	0	73		74	551	
2	0	0	0	0	0	0	12	0	12	1	0	0	2	1	5	16	68	93	105	
3	0	0		0		0	0	0	0	0	0	0	0	0	0	3	0	4	4	
4												0					0	0	0	
Total Permits	340	66	23	34	5	16	9	13	506	36	100	22	16	10	35	23	19	261	767	
Total VTR trip reports	3,165	445	123	288	116	139	68	83	4,427	1,165	829	497	120	172	286	281	171	3,521	7,948	
Total NEFMC fish landings,mt	458	4	0	262	12	242	388	2	1,367	4,554	1,823	1,469	349	1,135	945	2,004	297	12,577	13,944	63%
Total MAFMC fish landings, mt	23	1,000	0	4	8	5	10	13	1,063	0	1	1	0	0	8	13	6	29	1,091	5%
Total Joint NEFMC/MAFMC landings, mt	1,919	56	9	82	0	16	5	7	2,094	1,330	568	642	86	151	507	136	59	3,479	5,573	25%
Total ASFMC fish landings, mt	193	0	0	0	0	0	18	0	211	0	0	0	0	0	0	0	0	0	211	1%
Total HMS fish landings, mt	37	1	1	2	0	0	0	0	41	0	0	0	0	0	0	0	0	0	41	0%
Total Unmanaged fish landings, mt	689	40	0	0	0	0	36	411	1,175	1	1	0	2	1	6	92	68	171	1,346	6%

Zero permits means that a vessel had no limited access permit

The Council could take one of the following three approaches to address jurisdictional challenges and co-management of stocks that are caught within the Georges Bank EPU. The approach taken may also influence the options to allocate permits to fish within the Georges Bank EPU (see Section 9.5.1 for a discussion of options), or vice versa.

1. Set annual catch limits and manage fishing for only NEFMC and jointly-managed NEFMC stocks (i.e. Atlantic herring, monkfish, and dogfish) to achieve ecosystem goals and objectives.

2. Expand and develop a cooperative or co-management approach that includes all managed stocks that are caught in the Georges Bank EPU and set stock complex catch limits for the proportion of those stocks in the Georges Bank EPU.

3. Petition NOAA Fisheries for sole management of all or most fish stocks in the Georges Bank EBU.

Approach 1 above may seem the simplest and accounts for the majority of commercial landings, but it has some of the same fundamental issues that are associated with single-species MSY management via existing management plans. When appropriate data and analyses are available, this approach could account for expected biological interactions, but catches of stocks managed by other authorities would not be included as a component of FEP stock complexes and aggregate catches, thus limiting the value of an FEP to address technical interactions (i.e. bycatch and flexibility). It is also likely that with continuation of warming water temperatures, more species with historically southerly distributions (often managed by the MAFMC and ASMFC) will become a greater share of commercial and recreational fishery landings and catch. Approach 1 could be followed to initiate FEP management with a planned transition to approach 2 or 3.

The preferred approach is Approach 2, which is described below. Limited application of joint or co-management exists between the NEFMC and Canada, the MAFMC, and the ASMFC. In general, these joint or co-management arrangements have been successful but there have been some difficulties as well.

There are a number of ways that a co-management approach could develop, but it would promote achievement of EBFM objectives in the EPU through optimizing catch rates for all stocks and promote consistency with management objectives for the stock throughout the range. It would however require coordination and possibly approval of other management authorities for parts of an FEP that affect their species under management. Although the transboundary, coordinated management of three groundfish stocks with Canada is identified below as a possible template for co-management of Georges Bank EPU stocks, it must be recognized that for the Georges Bank EPU, coordinated management would involve more management agencies, including Canada, the MAFMC, the HMS Division of NOAA Fisheries, the ASMFC, and possibly states through ASMFC management to ensure compatible catch limits and consistency.

Approach 3 would mean that catches of the portion of all fish stocks within a Georges Bank EPU would fall under the management authority of the NEFMC. It may seem the simpler and most parsimonious with spatial management of fisheries in a FEP, but it would still require consultation and cooperation of transboundary stocks that are otherwise managed by other authorities. All species caught by commercial and recreational fisheries would be managed in a single plan with a consistent set of harvest control rules and regulations. Following a pre-established formula, this approach could account for the proportion of biomass in the EPU for a straddling stock but it could create a conflict between management goals established in one area for EBFM and other management goals to achieve single-stock MSY for the stock in other areas (or throughout the range).

There are other situations where stock assessments are done to estimate mortality and stock size throughout the range, but then the catch is partitioned or allocated between areas and each management body makes decisions for the portion of the stock in their area. An example of partitioned management of single stocks exists for the South Atlantic and Gulf of Mexico Fishery Management Councils that share snapper and grouper stocks, but have separate management plans.

NMFS is aware of a few examples where a single stock of fish is managed under separate FMPs adopted by different councils. While this approach provides direct control by each council within its area of jurisdiction, it can increase the resources needed for management, and may result in decreased management efficiency and success as actions taken by one council can impact management by other councils. For example, yellowtail snapper, mutton snapper, and black grouper are managed separately through the Reef Fish Fishery of the Gulf of Mexico and Snapper-Grouper fishery of the South Atlantic Region. For each species, scientific analysis show there is a single stock that occurs across both areas.[1] Currently, SSCs from the GMFMC and SAFMC must agree on an acceptable biological catch (ABC) based on the most recent stock assessment. Then, ABC is divided according to a jurisdictional apportionment identified previously in the 2011 Comprehensive ACL Amendment for the South Atlantic and 2011 Generic ACL/AM Amendment for the Gulf of Mexico. The jurisdictional allocations are based 50% on catch history from 1986/1990/1993[2]-2008 and 50% on catch history 2006-2008. The boundary between GMFMC and SAFMC is the Monroe County, FL line.

With any of the above approaches, the unmanaged fish could be considered as ecosystem component (EC) species, and managed accordingly, including the catch in appropriate stock complexes, and accounting for biological interactions to achieve FEP goals and objectives. EC stocks would not however have floors or minimum biomass thresholds that would define when they are overfished and in need of rebuilding.

9.4.1 Preferred Approach

Under existing governance and management authorities, any ecosystem production unit (EPU)- or place-based fishery ecosystem plan (FEP) will require a considerable amount of cooperation and coordination to be effective. Species and stocks managed by the NEFMC, the MAFMC, the ASMFC, NMFS (highly migratory species, lobsters, and striped bass in federal waters), coastal states, and Canada often have overlapping distributions and ecological interactions. The ecological interactions include predation and competition for resources (food, habitat, etc.), which must be taken into account and managed by the FEP.

Besides species-based management by a Council (or Commission, etc.), separate and often uncoordinated management of energetically-related species and stocks by different management authorities is at the heart of the issue supporting the need for ecosystem-based fishery management (EBFM).

Ideally, all authorities that manage interrelated fishery stocks need to collectively agree to common ecosystem constraints and the major FEP goals, else achievement of FEP goals would be severely compromised. This document discusses how the existing management authorities (NEFMC, MAFMC, ASMFC, NMFS-HMS, NMFS-PS, Canada, and coastal states) could cooperatively manage place-based fisheries, defined by EPU catch control rules.

A preferred approach is one that is loosely modelled after the US-Canada sharing agreement for Eastern Georges Bank fish stocks, a process that is familiar to many NEFMC members. To ensure consistent management of shared fishery resources, Congress passed the International Fisheries Clarification Act in 2010 and signed into law during 2011. For Eastern Georges Bank, the US and Canada appoint members to a Transboundary Management Guidance Committee (TMGC; see http://www.bio.gc.ca/info/intercol/tmgc-cogst/index-en.php) “to develop guidance in the form of harvest strategies, resource sharing and management processes for Canadian and US management authorities for the cod, haddock and yellowtail flounder transboundary resources on Georges Bank.” The parties agreed to core goals and objectives, as well as non-binding guidance on US and Canada harvest levels for Eastern Georges Bank cod, haddock, and yellowtail flounder. Sub-limits for each management area were approved through implementation of a resource sharing strategy and each country establishes technical measures that regulate fishing in the respective management areas. The resource sharing strategy relied on a combination of survey and historic catches to determine in each year the appropriate share to be allocated to each management authority. In recent years, the resource sharing agreement gradually shifted to reliance on relative biomass distributions measured by the two country’s bottom trawl surveys.

The NEFMC would serve as lead management authority for the Georges Bank EPU and management units within it. The Georges Bank EPU is entirely within the region that Congress identified as being managed by the NEFMC (See §600.105; http://www.ecfr.gov/cgi-bin/text-idx?SID=26405a30bb459dd8f241d50c77f40d8e&mc=true&node=se50.12.600_1105&rgn=div8).

Similar to the TMGC framework, a management board or advisory panel could develop a Georges Bank EPU resource sharing agreement as well as technical measures that would apply to MU fishing activities. The resource sharing could be based on a combination of survey and fishery data for each guild or functional group of Georges Bank EPU species. The NEFMC would review and approve of these recommendations under its Georges Bank EPU FEP. Allocations and measures that pertain to Georges Bank EPU species not managed by the NEFMC would also require review and approval by the appropriate management body. Although the role of the TMGC could continue to focus on the allocations of cod, haddock, and yellowtail flounder on Eastern Georges Bank, its role could also be expanded to include other ecosystem components of joint interest to both countries.

9.5 Limited Access and Authorization to Fish

The purpose of this section is to discuss how EPU permits could be structured, using limited access approach or letters of authorization to fish which are commonly used throughout many of our existing FMPs (see table below), applying to a place-based (rather than species-based) FEP. There are however many ways that such a permitting system may be developed as explained in the following section. If the NEFMC pursues a permit approach that relies on existing limited access permitting but requires documentation of fishing in the Georges Bank EPU, the Council would need to establish a control data and a suitable qualifying period.

Although catch limits would be specified and possibly allocated to vessels or groups of vessels, a limited access program is needed to prevent undue entry into the fishery (pl.), which could cause overfishing or depletion and dispersion of potential fishery benefits. This limited access program would obviously apply to commercial vessels, but may also be applied to all or segments of recreational fisheries.

Since many of the vessels in existing limited access programs are enrolled in more than one limited access program (see table below), often across different jurisdictions (NEFMC, MAFMC, ASMFC, HMS, etc.), the type of limited access program discussed here could apply to fishing for multiple stock complexes in the EPU, thus spanning multiple jurisdictions and may, in the end analysis, allow a vessel to fish for a species in its EPU that it is not currently authorized to fish. Conversely, a vessel that is permitted to fish for a species throughout its range, may be able to fish for that species only in other areas where it is authorized to fish. Vessels that had fished in multiple EPUs could also be authorized to fish in more than one EPU, but vessels with no history of fishing in an EPU would not be authorized to fish there in the future.

By the same token, a place-based limited access system would enhance profitability and have social benefits to coastal communities that rely on local (or in some cases distant) fishing activity. It also has the potential to reduce (or possibly eliminate) discards of valuable fish that would otherwise be caused by species-based limited access permitting. Fishing vessels with an EPU limited access permit would be able to fish for any species (subject to potential special situations below) that is available within the EPU, subject to catch limits defined by Species Complexes, and possibly other area-based regulations within the EPU (see Section 9.6.1). Thus, as species distributions, availability, and abundances change, vessels within defined EPUs would be able to target those resources with their place-based limited access permit, subject to ecosystem catch limit specifications.

We do not envision having different stock complex catch limits within the EPU, but it is possible that limited or special access permits could be defined such that a defined class of fishing vessels (large offshore vessels, for example) might have a permit to fish in one area within the EPU but not another. An allocation of catch to that defined Fishery Functional Group (FFG) might apply to that category of permit. Such an area within the EPU that where a special class of permits is authorized to fish would be called a management unit, or MU. It is also possible that there are no area boundaries within an EPU that distinguish where and when a permitted vessel could fish. It is also possible that other circumstances exist for vessels that do not hold a limited access permit, but have fished in the Georges Bank EPU using an open access permit. These vessels could be authorized to fish in the Georges Bank EPU via one of the non-limited access options (such as a Letters of Authorization) using their open-access permit.

A place-based limited access permit system could have the following characteristics:

1. **Qualification**
    a. Active: A vessel must have an existing limited access permit and have reported landings of species reported to have been caught within the EPU within a to-be-determined qualifying period. A vessel may also qualify if it had landings of species reported to have been caught within the EPU for a regulated species, such as whiting, not requiring an existing limited access permit.

    b. Inactive or history: If a vessel must have an existing limited access permit for a species that occurs within an EPU, but no landings that were derived from the EPU during the qualifying period, might be able to receive an inactive or history permit that might be activated under specific circumstances.

    c. Special exceptions: Vessels may have a limited access permit for a special exception fishery (such as sea scallops, red crab, surf clams/ocean quahog, or lobster), but may receive a place-based limited access permit only if it had a history during the qualification period of landing other species caught in the EPU.

2. **Permits**
    a. A standard limited access permit would be required to fish within the EPU and the vessel could target any species not covered by a special exemption using any gear (subject to technical limits set by the EPU Management Board and approved by the applicable jurisdictional authority, e.g. NEFMC, MAFMC, ASFMC, NMFS, states (for state water vessels).

    b. Vessels may fish for and land species that are covered by a special exemption (described above) using gears that are regulated by that permit.

c. A vessel may need only ONE standard limited access permit for an EPU to fish for and land any species not covered by a special exemption. Vessels that are authorized to fish in more than one EPU will need to qualify for and hold a standard limited access permit for EACH EPU, but may land fish at any port.

3. **Permit stipulations**
    a. A permit holder may not accrue permits and/or catch allocations that exceed a specified percent of the total for an EPU.

    b. No limits on length, HP, or GRT will apply (since stock complex catch limits and allocations to fishery functional groups would make such increases unprofitable unless the vessel or permit holder obtains more allocations through permit transfers or other means).

4. **Catch limits and allocations:**

    Vessels or groups of vessels (e.g. 'sectors') or all limited access EPU permit holders may catch up to the Species Complex catch limits. Species Complex catch limits within an EPU could be based on a) the EPU stock complex catch specifications and b) the proportion of EPU catches previously (qualification period?) made by vessels with a limited access perpmit or authorization to fish in the EPU. When allocated to vessels or groups of vessels, Species Complex catch limits will be based on a vessel's prior landings of all regulated species (during qualification period?) reported to have been caught within the EPU. Overages will be subject to future adjustment through accountability measures.

Table 7. List of existing limited access permits and their characteristics that currently apply to fishing within a Georges Bank EPU (Statistical areas 525, 526, 561, 562, and southern overlapping portions of 521 and 522).

Permit and jurisdiction	Species which may be landed using permit	Permitted vessels (2018), Number with Georges Bank EPU landings[14]	Qualification criteria and period	Top three overlapping[15] permits by vessels with Georges Bank landings
NE Multispecies Limited access (NEFMC)	Cod, haddock, yellowtail flounder, etc.	876/210		Monkfish (128) Lobster (178) Skate (188)
Monkfish Limited access (NEFMC/MAFMC)	Monkfish	557/259		Lobster (212) Summer flounder (218) Skate (243)
Skates Open access (NEFMC)	Little, winter, rosette, clearnose[16]	1944/751	Pending	Lobster (484) Scallop (322) Summer flounder (359)
Atlantic herring Limited access (NEFMC)	Herring	82/42		Skate (34) Summer flounder (33) SMB (36)
Black sea bass Limited access (MAFMC)	Black sea bass	645/191		Skate(175) Summer flounder (180) Scup (170)
Scup Limited access (MAFMC)	Scup	597/147		Black sea bass (123) Summer flounder (133) Skate (184)
Squid, mackerel, butterfish Limited access (MAFMC)	Illex and loligo squid, Atlantic mackerel, butterfish	1044/147		Skate(135) Scup (128) Summer flounder (133)
Small-mesh multispecies Open access (NEFMC)	Whiting, red hake	782/248		Skate (237) Scallop (166) Summer flounder (145)

[14] Skate totals are open access permits – limited access is currently under consideration. Small-mesh multispecies permit totals are open access permits

[15] Permits held in common by a single vessel.

[16] Barndoor, smooth, and thorny skate landings are subject to limited access permitting, but may not be currently landed due to being overfished or being in a rebuilding plan.

Permit and jurisdiction	Species which may be landed using permit	Permitted vessels (2018), Number with Georges Bank EPU landings[14]	Qualification criteria and period	Top three overlapping[15] permits by vessels with Georges Bank landings
Summer flounder Limited access (MAFMC)	Summer flounder	719/359		Lobster (263) Skate (331) Scallop (277)
Sea Scallops Limited access (NEFMC)	Sea scallops	342/322		Skate (299) Summer flounder (277) Lobster (209)
Sea Scallops, General Category Limited access (NEFMC)	Sea scallops	571/271		Lobster (169) Skate (245) Summer flounder (192)
Surf clams/ocean quohogs Open access (MAFMC)	Surf clams, ocean quohogs	618/373		Skate (334) Scallop (269) Summer flounder (274)
American lobster Limited access (NMFS/ASMFC)	American lobster	2790/484		Monkfish (212) Fluke (263) Skate (352)
Red crab Limited access (NEFMC)	Red crab	5/1		NA
Bluefin tuna (NMFS)	Bluefin tuna			
Atlantic sharks	Various sharks			
Etc.				
Total number of vessels with any limited access permit		???/434		

9.5.1 Permit and allocation approaches

Similar and potentially related to how a FEP developed by the NEFMC interacts with other management bodies (see Section 9.2), a range of potential permitting options could be considered. These options also could be considered in relationship to potential choices of incentive-based measure approaches described in Section 9.1.3. Combining permits into one governing a type of fishing activity (e.g. bottom trawl fishing) in a specific area (e.g. EPU) could improve accommodation of technical interactions and reduce cost. Such an approach could also be more aligned with allocations of catch by stock complexes, particularly when stock complexes are comprised of similar species managed by other management bodies.

This section describes the following potential permitting approaches as concepts, as well as strengths and weaknesses of each. Specific details, the number of permits to be issued and qualification requirements are not discussed here. While the permitting itself is not something that can be modelled, the potential approaches might be considered in the evaluation of management strategies that estimate the relative amount of technical interaction that could occur or the amount of cost associated with fishing under a system of permitting that is more parsimonious with EBFM compared to options that are not. These permit options are described in more detail in Section 9.5.1.1.

1. No additional permit required (No Action), but vessels would declare into a Georges Bank EPU fishing mode (métier) for monitoring catch
2. EPU/Gear Overlay – additional permit needed to fish within the GB EPU
3. A letter of authorization (LOA) to fish on Georges Bank with existing permits
4. Hybrid EPU permit – new permit to fish with specific gear within the GB EPU and land NEFMC-managed species
5. EPU/Gear permit – Vessels with history of using a gear in the Georges Bank EPU may obtain a permit to fish and land all species associated with that fishing mode (métier).

Recently, there were 767 vessels that landed fish caught in the Georges Bank EPU (approximated by statistical areas) in 2018 (Table 5). Of these, 261 held either a joint monkfish or dogfish permit and 506 held neither. Only 5 vessels (3+1+1) had a MAFMC limited access permit but did not have a NEFMC limited access permit. However, there were 151 vessels (340+36-225 open access only permits) that held a NEFMC limited access permit, but not a MAFMC permit.

A new permitting approach could take the form of a permit overlay, such as a Letter of Authorization, to fish within the EPU using existing permits, or allow authorized vessels to obtain a permit to fish in the EPU with specific fishing gear or method and retain any species for which there is an allocation. The latter method could make allocations of stock complexes easier to manage. For purposes of evaluation, we can start with an assumption that any vessel with a limited access permit and history of fishing within the Georges Bank EPU would receive a new EPU permit or Letter of Authorization. Distinct single species fisheries such as scallop, lobster, and red/Jonah crabs might not require a different permit than they have now, but how bycatch of stock complexes would need to be defined.

Stock complex catch allocations could be based on the EPU permitting (possibly with incentive-based measures that apply to them). The catches in the EPU could also count against stock catch limits for transboundary stocks that are managed by the NEFMC or others, managed in a similar way that they are for the Eastern Georges Bank co-managed (US-CAN) stocks (see Section 9.4).

- While evaluating these options, some additional questions should be considered:
- Since qualification periods for individual fisheries (as currently defined) differ, how would a vessel qualify to fish with a specific gear in the Georges Bank EPU?
- What is the qualified vessel entitled to do? What are the limitations of the qualification? Can vessels with Georges Bank EPU history with one gear type obtain a permit for a different gear type?
- Are Georges Bank EPU permits and allocations consistent with stock allocations (for species managed by MAFMC, ASMFC, and HMS) and monitoring?

- Catch allocation can be discussed separately, but assuming that there is some sort of EPU/gear permit, what catch allocation systems would be compatible with other systems currently in use? Catch shares, sector allocations, a simple cap without an allocation to a permit?

- If single species fisheries (e.g. lobster, scallop, red crab) are not included in scheme, would they still need a permit for bycatch or land incidental catch of managed finfish?

- Would LAPP regulations apply to these types of permits and potential allocation schemes?

- How would this work if there is an inconsistency between GB EPU catch limits and state landings limits?

- What types of fishing Georges Bank occurs by vessels with only open access commercial permit? How should they be permitted in an ecosystem plan?

9.5.1.1 Permit options

No additional permit required (No Action), but vessels would declare into a Georges Bank EPU fishing mode (métier) for monitoring catch

This approach would obviously have no additional permitting costs or any qualification procedure. On the other hand, some vessels that fish in the EPU would not have the permits they need to land species that are in a stock complex whose catch is allocated to them. It wouldn’t reduce the number or cost of their permits, either, but it would probably require an additional trip type declaration (similar to the one that applies to fishing in the Eastern Georges Bank area, having catch limits negotiated with Canada). Vessels from more southerly ports are less likely to have NEFMC permits if they target MAFMC species within the Georges Bank EPU. On the other hand, vessels with existing permits to fish anywhere could take new or additional trips to fish in the Georges Bank EPU.

If this option were analyzed through simulation, the evaluation would need to assume that a vessel without the necessary permit would discard fish or it would require the vessel owner to obtain the needed permit through lease, sale, or transfer.

EPU/Gear Overlay – additional permit needed to fish within the GB EPU

For this option, vessels that have a history of fishing in Georges Bank could obtain a permit to fish with specific gear(s) in the EPU. This strategy could be used as a transitional step, because it could be compatible with the existing permitting. The advantage over the first option is that the number of vessels that can fish in the Georges Bank EPU would be limited. The permit could be associated with special requirements and receive EPU stock complex catch allocations.

This option would not allow a vessel without an existing permit to retain a species to keep those fish in the Georges Bank EPU, but it would prevent new vessels coming from elsewhere to fish Georges Bank and allow stock complex catch allocations to be associated with a permit. The cost of obtaining this overlay permit would add to permitting and administrative cost.

A letter of authorization (LOA) to fish on Georges Bank with existing permits

Like existing Letter of Authorization programs, any vessel with an existing permit could apply and fish in the Georges Bank EPU, but the Letter of Authorization could carry specific conditions (such as a trip declaration and possibly a catch allocation).

The cost of obtaining this type of Letter of Authorization would add to permitting and administrative cost. It also would not limit the number of vessels that can fish with various gears in the EPU and would not reduce bycatch if the vessel did not have a permit to retain a species that is part of a stock complex allocation.

Hybrid EPU permit – new permit to fish with specific gear within the GB EPU and land NEFMC-managed species

This approach would replace NEFMC permits to fish within the Georges Bank EPU, but would not replace permits issued by the MAFMC, the ASMFC, and the NOAA Fisheries HMS. It could allow the Council to allocate stock complex catch limits to vessels with permits, but it would not reduce bycatch for MAFMC, ASMFC, or HMS stocks for which a vessel has no permit. This option would be more compatible with an EPU catch allocation framework if the Council chose to include only NEFMC and jointly-managed NEFMC stocks. Depending on how a vessel qualifies (e.g.. by using a specific gear in the EPU), this option could lock vessels into a gear they have used, inhibiting innovation and gear switching.

EPU/Gear permit – Vessels with history of using a gear in the Georges Bank EPU may obtain a permit to fish and land all species associated with that fishing mode (métier).

This type of permit could be compatible with stock complex catch allocations for the EPU. Discussed in Section 9.4on jurisdiction approaches and co-management, stock complex catch allocations would include all Georges Bank species and would need to be consistent with single stock limits for MAFMC, ASMFC, and HMS unless the stock is primarily a Georges Bank stock.

This option could reduce permit and administrative costs by replacing all existing permits when fishing in the Georges Bank EPU, but existing permits would still need to be obtained to fish elsewhere. It has the potential to address technical interactions and reduce bycatch, while being used to incentivize the use of less impactful gears.

9.6 Fishing impacts on ecosystem and spatial management

This section describes some strategies to achieve an ecosystem management goal of sustaining and improving productivity of managed and protected species through sustaining and restoring habitat quality, resulting in increased survival of new recruits and optimal conditions for feeding and reproduction.

This eFEP management strategy component is not intended to duplicate or replace the Omnibus Habitat Amendment 2 measures, but instead broaden the scope of considering spatial effects of fishing as they relate to ecosystem function, including effects on juvenile survival and growth, energy flow through the system, and abundance and availability of prey for apex predators and protected species. The intent is to focus on the role of spatial processes on ecosystem function and health, as well as the benefits accrued from taking these processes into account in order to minimize risk to managed populations. A recent example where such processes were explicitly addressed was in Amendment 8 to the Herring FMP. In

Amendment 8, several spatial alternatives and their potential effects were considered to reduce the effects of fishing in coastal populations of herring, an important prey species.

Listed below are four management strategies that would focus on the role that quality habitat has to improve ecosystem productivity and broaden the scope of consideration about the role of quality habitat in the ecosystem. These strategies focus on issues that are fundamentally different however from protecting mainly habitat that is vulnerable to adverse effects of various types of fishing effort or that take a relatively long time to recover from such disturbance caused by fishing. Instead, the issues recognize the importance and scale of spatial processes and demographic characteristics of fish in the "local" environment, i.e. how species interact on smaller spatial scales. Broadly speaking, these ecological "assets" include quality habitat for juvenile fish survival and growth, maintenance and enhancement of spawning potential (not just the amount of spawning biomass, but consideration of where and how spawning takes place), and quality habitat and forage fish availability to marine mammals and other apex predators.

9.6.1 Spatial management approaches

Potential spatial management approaches to address management objectives for habitat, spawning and protected species include:

1. Assessing spatial distribution of effort by gear type and fishery functional group to evaluate patterns of impact and recovery to habitat, spawning, and protected species within each EPU.

Rationale and general approach: Quantifying spatial and temporal variation in fishing effort by gear type, linked to spatial variation of habitat types within EPUs. The output could be used to assess effects of fishing on vulnerable attributes of habitat and the potential for interactions within and between fishery functional groups and protected species. Geospatial data products, based on the SASI model framework, can be used to assess spatial variation of habitat impacts in regard to recovery rates, timing of gear effects, and co-occurrence with managed and protected species.

2. Evaluate allocations of catch to fishery functional groups to achieve management objectives for habitat, spawning, and protected species within each EPU.

Rationale and general approach: Evaluate spatial distribution of catch based on gear-effort and fishery functional groups where: (1) impacts to habitat are highest and where recovery times longest, (2) highest effort coincides with important life-history stages of managed species (e.g., settlement), and (3) where fishing coincides with aggregations of protected species (e.g., based on patchiness of distributions). Evaluate management objectives and approaches to reduce effects through the allocation process. This should be an adaptive process to identify where interventions could enhance ecosystem objectives and where (collaborative) research could be implemented to test responses and refine assumptions. Interventions could include gear restrictions, time-area rotations or closures, or allocating catch/effort such that some areas are fully fished, some are moderately fished and some areas lightly fished or closed. The intention would be to ensure high quality habitat at all life stages to support productive fisheries and reduce technical interactions among protected species and the fleets.

While the effects of fishing are often measured as effort, i.e. hours and area of bottom contact with gear, the currency in the FEP that influences how much fishing effort occurs within the EPU is catch of fishery functional groups. To achieve EPU-wide objectives, decisions about catch allocations may take habitat, spawning, and protected species impacts into account, particularly when other more direct means of minimizing impacts and improving productivity through more direct measures like area restrictions and more selective gear are highly uncertain and variable.

3. Estimate effort and gear impacts to habitat for each managed species (or complex/functional group) regarding variation in productivity (growth, survival, reproduction) to evaluate performance of management to meet habitat, spawning, and protected species management objectives.

Rationale and general approach: The role of habitat is a primary but not exclusive factor mediating the demography of managed species. In order to develop alternatives for habitat management that conserve habitat and sustain or enhance managed species, a modeling approach that evaluates variation in habitat attributes and links to the life history of managed species is needed. The EcoPath-EcoSpace model platform, for example, can be used to predict population responses to variation in habitat attributes, that affect survival and energetics, based on implementation of foraging arena theory. Models can test multiple impact and intervention scenarios that can be used to further inform allocation decisions and research needs.

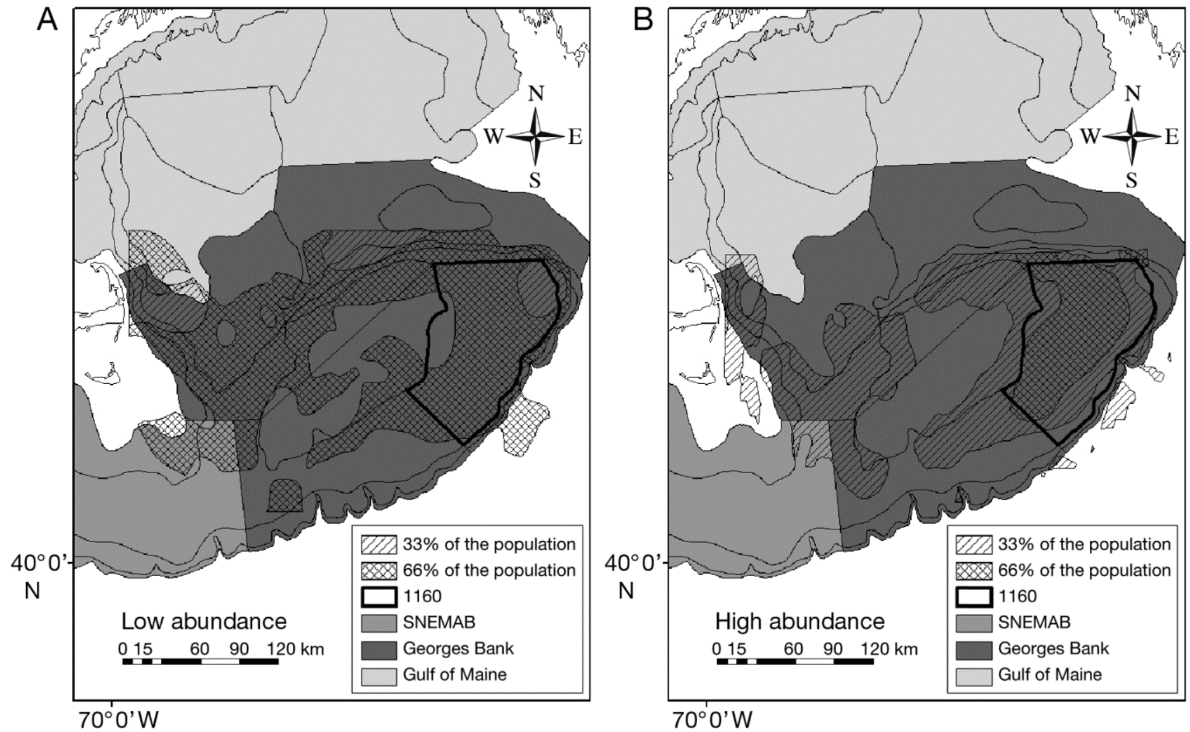
4. Effects of spatial variation in demographics of prey species for managed and protected species.

Rationale and general approach: The spatial variation in density, size, and patchiness of prey available to predators directly affects patterns of energy intake and subsequent patterns of survival, growth, and reproduction. Analysis of existing data sets (split-beam acoustic surveys, trawl survey and observer data) for spatial distribution of principal prey (e.g., Atlantic herring, sand lance, mackerel, pollock, decapod zooplankton) over seasonal periods with comparison to patterns of catch, and patterns of protected species, can inform development of spatial management alternatives related to protected species interactions with fisheries.

9.6.2 Research needs

As an initial examination into spatial variation, condition factor for managed species could be examined spatially with data from the NEFSC trawl survey (e.g., Pereira et al. 2012, 2014, Howell et al. 2016). Data could be analyzed to determine if there were consistent patterns in variation in condition across Georges Bank (Northeast Shelf) by season and over time and if the patterns in condition factor were correlated with habitat types (taking sex, size, and population level into account). The goal would be to identify productive areas or habitat types that could help define spatial regions that enhance fish productivity and could be examined in simulation testing and adaptive management actions. For example, Pereira et al. (2012) demonstrated that data collected during standard fisheries assessment surveys (size, sex, weight, abundance, location) could be used to quantify spatial patterns of habitat use for yellowtail flounder on Georges Bank and identify areas that make significant contributions to species productivity (Map 2).

Map 2. Example of a geospatial approach for identifying habitat areas that contribute significantly to productivity (from Pereira et al. 2012). The maps illustrate the distribution of yellowtail flounder population on Georges Bank during periods of (A) low and (B) high abundance. The cross-hatched area represents the area within which approximately 66% of the population occurred. The hatched area represents the distribution of an additional 33 % of the population. Together they account for 99% of the area occupied by the population. Analysis of spatial pattern revealed that the overall area occupied by flounder increased by a factor of 2 when abundance was high, and local density increased predominantly in high quality habitat, with quality based on variation in size-weight relationships.



9.7 Environmental Impact Statement (EIS)

Every five years or another period that meets NEPA requirements, the NMFS and its management partners will develop or supplement an EIS which will incorporate information in the Affected Environment (see below) as well as evaluate cumulative effects of the status quo and alternatives. It is intended that the measures developed for the MUs will be evaluated by tiering off this EIS.

9.8 Catch Monitoring, Ecosystem Data Collection and Research to Support EBFM in New England

The US NE shelf is one of the most sampled areas of the world. Long-term time series go back decades providing the foundation for fisheries science and management. The extensive data has enabled the development of ecosystem and food web models to understand the connections among species and trophic levels and supports the development of ecosystem-based fisheries management (EBFM). While all monitoring and research programs have room for improvement, the Fishery Ecosystem Plan (FEP) can be implemented with the current data collection and analysis systems in place today on the US NE shelf.

Currently, the extensive amount of monitoring on the US northeast shelf lays the groundwork for EBFM. The data requirements for the FEP could build off of existing programs, particularly the trawl survey, ECOMON cruises, Food Habits data base, additional fisheries surveys (e.g. long-line, fixed gear), habitat studies, protected species surveys and socio-economic data programs along with the required post survey lab work and analyses. The NMFS also collects a huge amount of information on catch and discards from commercial and recreational fishers. The information on landings, discards, lengths, locations and timing represents an essential component of the management framework on the northeast shelf.

While all monitoring and research programs have room for improvement, the Fishery Ecosystem Plan (FEP) can be implemented with the current data collection and analysis systems in place today on the US NE Shelf." It supports this view in the sense that shortcomings and limitation of current monitoring programs are risk factors that degrade the quality of stock assessments and monitoring under the current management regime, and these risks are not necessarily exacerbated by EBFM. However, in the process of formulating EBFM and evaluating it using MSE, the Council expects specific data problems that are worsened by applying EBFM to be identified along with proposals for mitigating the problems. MSE is also a tool that might identify management approaches that are more robust to uncertainties in monitoring data than current management approaches

With the intension of improving the information upon which management decisions are made, the New England Council has developed a list of additional monitoring and research priorities. These priorities are designed to improve decision making, but do not preclude decisions from being made. Similarly, a number of the Council's monitoring and research priorities would also enhance the decision making within EBFM.

One of the goals of EBFM is to manage fisheries within the limits of the supporting ecosystem, thereby maintaining an ecologically resilient and functional system. EBFM explicitly acknowledges the interactions among species, humans and the physical environment and therefore must monitor and understand all the components. The FEP also strives to make management more adaptable and responsive to the current conditions on the water. To capture the full picture of what is happening on the northeast shelf and decrease the time period between signal and response, increasing the spatial and temporal resolution of sampling, as well as better information about diets and productivity, species interactions, oceanographic information, and species association for commercial and recreational catches could improve the execution of management. As always, verifiable data that accurately identifies what is happening in and on the water is essential for long-term sustainable management. Increased involvement and participation by fishermen in these data and information collection activities, either by enhanced data collection on fishing activity and catches or by participation in surveys and research, could serve to increase overall capacity as well as increase stakeholder participation.

New or expanded types of environmental monitoring could improve our understanding and management of the ecosystem in a more adaptive and responsive way, but collecting these data will have costs. These costs, however, may be offset by less frequent sea sampling that is replaced by onboard electronic monitoring of catch, oceanographic, and biological conditions.

Accurate catch monitoring is important, regardless of whether stocks are managed singly or as an ecosystem, but there are no novel catch monitoring issues to be addressed in the eFEP. Although catch accounting may occur for aggregate groups of species (i.e. by 'fishery functional group'), removals by stock will still be needed to assess stock condition and evaluate the biological/energetic relationships among them.

It will be as important for EBFM as it is now for single-species management, but part of the concept behind our view of a FEP is that it would be more flexible and adaptive than current management procedures. Thus more timely and accurate data will be needed to understand changes that occur. One of the ways to do this is to improve the State of the Ecosystem report, adapting it so that the results are more actionable and integrate ecosystem trends into assessments and the processes for setting specifications.

In either case, unbiased and accurate landing reports and discard estimates for commercial and recreational fishing will be needed and should be improved. The Council believes that the use of catch and survey data in assessments and in management should be streamlined and transparent. Operating models used to evaluate management strategies should account for a range of time lags between data collection, assessment, and management response as well as evaluate uncertainty in how survey indices of biomass and abundance track actual population trends.

Additional monitoring and research that could enhance the already extensive programs in place to support EBFM are outlined below. The data collection, ecosystem research and monitoring items identified below are largely derived from the New England Council's monitoring and research priorities or align with them.

9.8.1 Modernize Data System

a. Both to support the current science and management and to support any expansion in monitoring, an investment in data infrastructure could produce significant gains. A modernized data system that contains all needed information for fisheries research and management in a single, centralized location, can handle a range of data types, ensures confidentiality for certain data types and enables fishers to access their own catch data is an important component to support the monitoring and research needs of any management system and is only elevated under EBFM.

9.8.2 Catch monitoring (i.e. landings data and discard estimation for stocks and stock complexes) to achieve better accountability and address potential bias in estimating removals.

b. Increased communication and reporting among vessels with the inclusion of scientists that analyze data in real time to identify hotspots of target and non-target species in order to minimize discards and protected species impacts while maximizing catch.

c. Work toward full accountability by creating verifiable catch data with increased observer coverage and/or electronic monitoring.

9.8.3 Ecosystem data collection (i.e. oceanographic, biological, and socio-economic data related to estimating and projecting productivity and ecosystem structure)

d. Surveys of resources not captured by trawl survey gear because of behavior or habitat e.g. pelagic and rocky habitat species via long-line, fixed gear, imaging, or acoustic surveys.

e. Continued and expanded sampling of trends in non-target, ecosystem components. This would include non-target species, protected species, lower trophic level species, oceanographic features mediating distribution of eggs, larvae, and juvenile fish, with sampling at an increased spatial and temporal scale.

f. Increase the information available for research and management in both quantity and spatial-temporal resolution. One potential approach is to outfit fishing vessels to collect oceanographic data, timing and location of species, spawning areas, and habitat associations.

g. An expanded collection and use of social and economic indicators. For all fisheries: (1) Characterize the vessels, firms, organizations, and communities involved; (2) Identify capacity use and fixed costs; (3) Characterize stakeholders besides directed fishery participants; (4) Characterize dealers and processors (e.g., dependence on fishery, location, costs, earnings, employment); and (5) Characterize market dynamics (e.g., relationships between fishermen, buyers, and processors; and end users; intra and inter sector quota lease price).

h. Targeted habitat and gear effects data collection programs to support ecosystem research.

9.8.4 Ecosystem research (with participation by fishermen) to understand the status, dynamics and function of the ecosystem, as well as distribution/migration and stock structure.

i. Continued catchability studies with the potential to improve the use of survey indices as species (and stock complex) abundance indicators as well as improve the inputs into stock assessments.

j. Complementing the NEFSC food habitats data base, directed, long-term studies measuring the consumption of different predator species to directly parameterize predator-prey studies and ecosystem/food-web models.

k. With the shifts in distribution of many species, investigations into stock definition, stock movements, mixing, and migration through tagging studies, DNA markers, morphological characteristics and other means.

    i. Additional studies into the proportion of a stock within an EPU and how that changes across all EPUs seasonally and annually. Although stock complexes are expected to be more robust to changes in distribution from climate change, it is important to understand the linkages with neighboring EPUs and how long stocks reside within the EPU to develop catch advice.

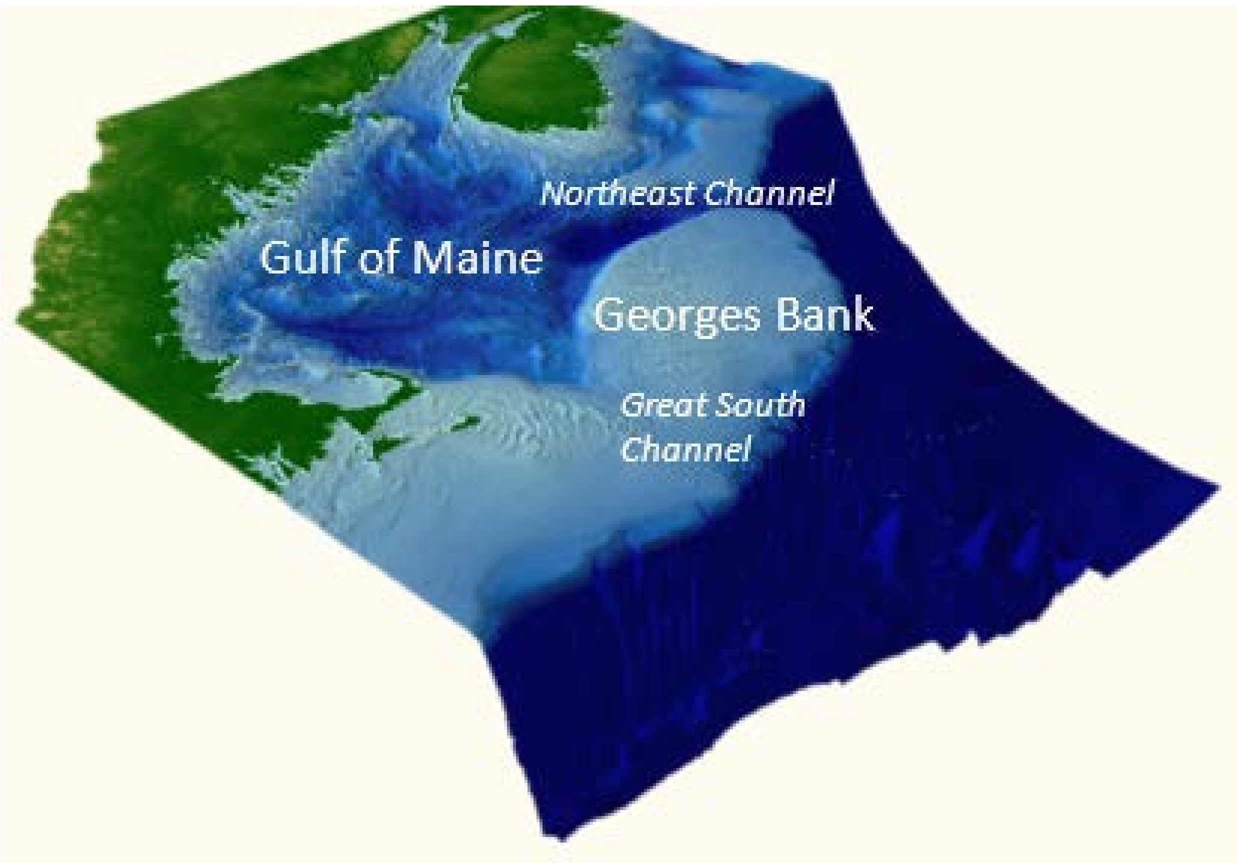
l. Improved sampling and characterization of different habitats, inclusive of the biotic, static and dynamic components (e.g. benthos, substrate, oceanographic features), how they vary over time and how the habitat mediates the abundance and distribution of natural marine resources (target, non-target, protected species).

m. Continued work examining the connection between primary productivity, energy transfer and biomass of higher trophic levels: Fishery production is directly related to the amount of energy coming in at the base of the food web through phytoplankton production. Phytoplankton production is estimated using satellite observations and is calibrated using direct shipboard sampling when possible. Estimates of small- and large-celled phytoplankton production are currently used directly in the NEFSC Fishery Production Potential (FPP) model and in Ecopath with Ecosim (EwE). The FPP model uses externallyderived estimated of energy transfer efficiency . EwE production estimates can be used to internally estimate transfer efficiencies. Currently and EWE model is under development for Georges Bank and when available, these new estimates of transfer efficiency can be used in the FPP model.

10.0 Description of the Georges Bank Ecosystem

Georges Bank is a shallow-water, highly productive submarine plateau located off the New England coast (Map 3). The bank encompasses approximately 40,000 km^2 within the 100 m isobath and is delimited by deep-water channels on the northeast and southwest (the Northeast Channel and the Great South Channel respectively; Map 3)). The physiography of the region contrasts sharply with the adjacent Gulf of Maine, a semi-enclosed continental shelf sea, characterized by an extremely complex physiographic structure. Three major deep basins, over 20 smaller basins, and two relatively large ledge-bank systems occur within the Gulf of Maine proper. These physical characteristics provide a sharp demarcation between Georges Bank and the Gulf of Maine that result in important differences in their production characteristics and ecological structure.

Map 3. Topography of Georges Bank and the Gulf of Maine



The region has supported important commercial fisheries for over four centuries (German 1987). Georges Bank has been the focus of detailed physical and biological oceanographic studies since the turn of the century. Comprehensive overviews of the geology, physics, ecology, and fisheries of this region are provided by Backus (1987) and Sherman et al. (1988). Recent changes in abundance, yield, and community structure of fish populations on Georges Bank have highlighted the need to understand the factors affecting production at all trophic levels (Fogarty et al. 1987). Georges Bank is further recognized as a faunal transition zone that may be particularly sensitive to the effects of global climate change (Frank et al. 1990; Mountain and Murawski 1992; Murawski 1993).

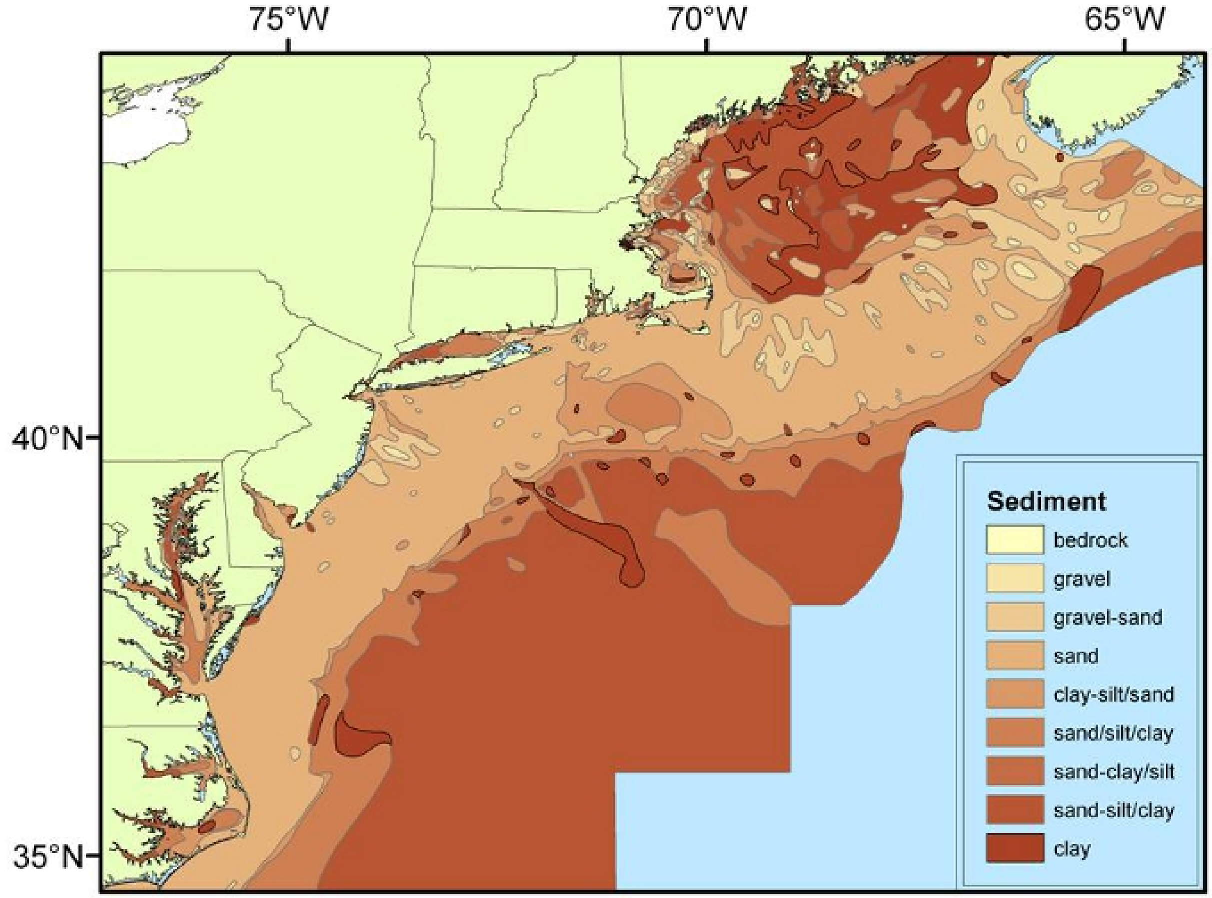
10.1 Benthic Habitats

The surficial sediments of Georges Bank are dominated by large expanses of sand substrate, interspersed with gravel and gravel/sand regions (Twichell et al. 1987; Map 4). In some regions of the bank, notably the crest, large sand waves of up to 20 m dominate the topography (Uchupi and Austin 1987). Gravel regions occur along the Northeast Peak and in isolated pockets on the central plateau of the bank and in the vicinity of on the southwestern section near the Great South Channel. Interspersed within the gravel regions are large glacial erratics and boulders that further increase structural complexity and provide refuge sites for a diverse assemblage of organisms including fish. The sediments on the bank are constantly reworked by strong tidal currents and the episodic effects of storms. Storm-induced disturbance is most prominent in the sand substrate regions on the shallow central plateau of the bank (Butman 1987). The impact of storms on sand substrate regions can be expected to diminish with depth and with increasing grain size and compaction of the substrate.

The gravel region on the Northeast Peak is known to be an important habitat for the early demersal phase of cod and haddock (Lough et al. 1989). These stages are cryptically colored with respect to the gravel, reducing predation risk (Lough et al. 1989). Survivorship of juvenile cod is known to be higher in substrates with higher structural complexity (Gotceitas and Brown 1993; Tupper and Boutilier 1995). It has been suggested that the gravel substrate may represent a limiting resource for the early life stage of cod and haddock (Langton et al. 1996). The gravel pavement on the northeast peak and similar areas along the northern edge of the bank are further recognized as important spawning locations for Atlantic herring which lay demersal eggs in adhesive layers on gravel and coarse sand substrates.

It has been inferred that the gravel regions, which support a rich epibenthic fauna, are particularly vulnerable to the effects of disturbance by fishing gear. Such concerns are, in fact, of longstanding interest on Georges Bank (Alexander 1915; Herrington 1948). Reduction in structural complexity in these habitats would result in the loss of important shelter sites for many fish species (Langton et al. 1995, 1996). Biogenic structures, particularly polychaete and amphipod tubes, can also provide shelter sites for juvenile fish and other organisms in regions of otherwise low structural complexity, including sand substrates. Sandy regions dominated by such structures would also be highly vulnerable to disturbance by fishing gear (Auster et al. 1995; 1996).

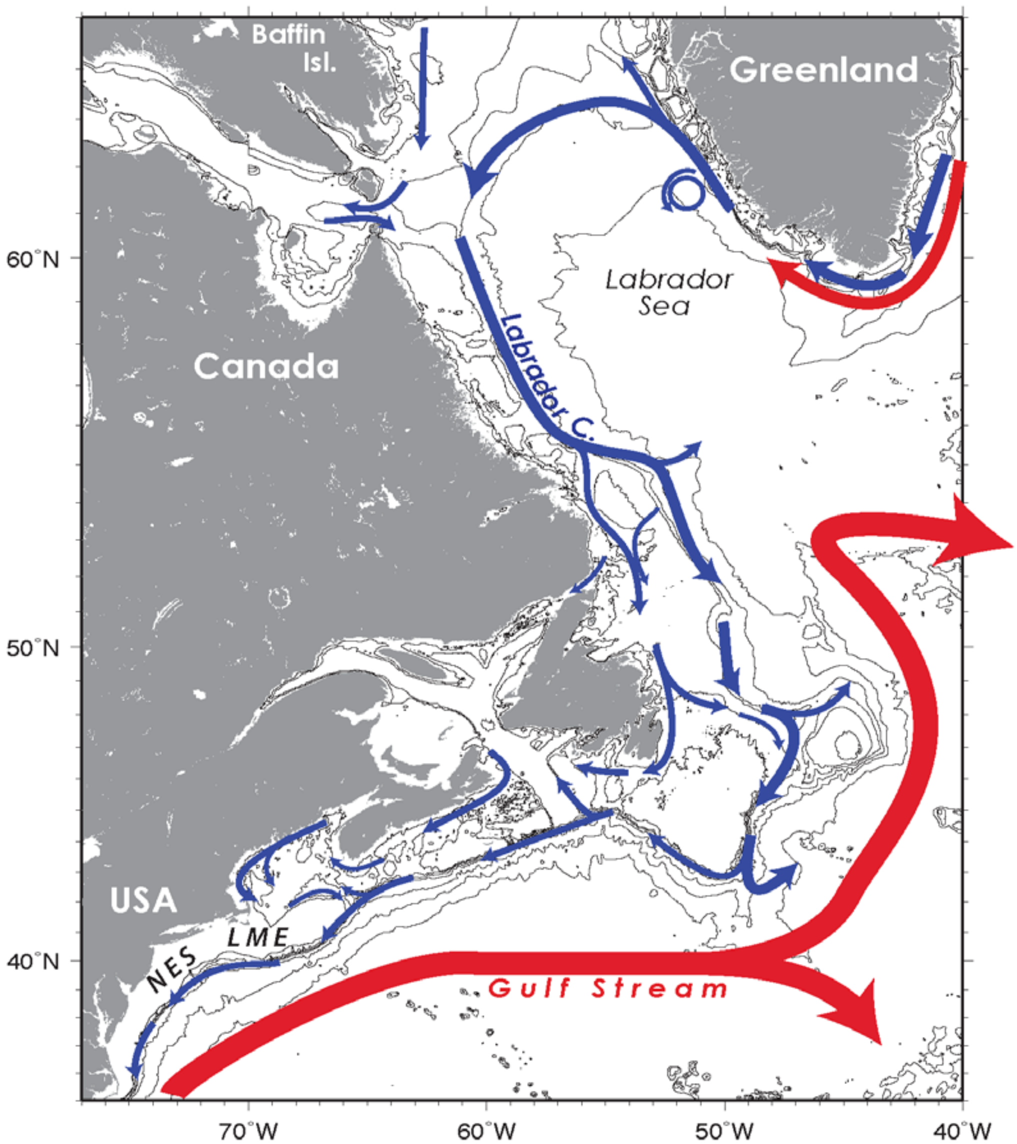
Map 4, Sediment distribution on the Northeast US Continental Shelf.



10.2 Oceanographic Setting

The oceanography of the NES LME as a whole is shaped by a number of factors including the flow of water from the north into our region, the influence of major river systems, winds, and tidal forces. The physical oceanography of the region is further strongly influenced by two major current systems, the equatorward flowing Labrador Current from the north and the poleward flowing Gulf Stream (Map 5). Hydrographic characteristics such as temperature and salinity and oceanographic features such as circulation patterns and the position of frontal zones affect every aspect of the ecology of the system, including the distribution patterns of species at all levels of the food web, the basic biology of individual species, and dispersal and migration pathways. The Gulf Stream, a classic western boundary current system, driven by wind fields and serving as a major mechanism of heat redistribution in the North Atlantic exerts important influences on the Georges Bank, particularly through the formation of meanders and eddies that can impinge on the bank Warm core rings - meanders that separate from the Gulf Stream and form a clockwise rotation pattern - can draw large volumes of water off the bank, along with the phytoplankton and zooplankton in that water.

Map 5. Principal circulation features on the NES LME and adjacent offshore regions showing equatorward flow of shelf and slope waters and poleward flow of the Gulf Stream with a warm core ring depicted



Tides and topographic features of the Georges Bank region result in the establishment of an anticyclonic (clockwise) circulation pattern, particularly during the stratified period, on the bank. This semi-closed gyre holds important implications for the retention of planktonic organisms on the bank. A strong tidal circulation 'jet' forms on the steep northern edge of the bank and continues in more diffuse form around the northern edge and its southern flank. In the general flow, some water exits over the Great South Channel while the remainder recirculates on the bank. It has been estimated that the average retention time of a parcel of water (and associated organisms) is approximately 5 months during the stratified season and on the order of two months in the remainder of the year.

On Georges Bank, strong tidal forces keep the water on the shallow crest of the bank (<60m) well mixed and isothermal throughout the year. Recent evidence suggests the importance of cross-over events from the Scotian Shelf onto Georges Bank, particularly in winter and short-circuiting the 'typical' pathway of water exchange from the shelf to the bank. The salinity on the bank is relatively stable and slightly higher than the Maine Surface Water, suggesting an influence from slope waters or deeper waters in the Gulf of Maine.

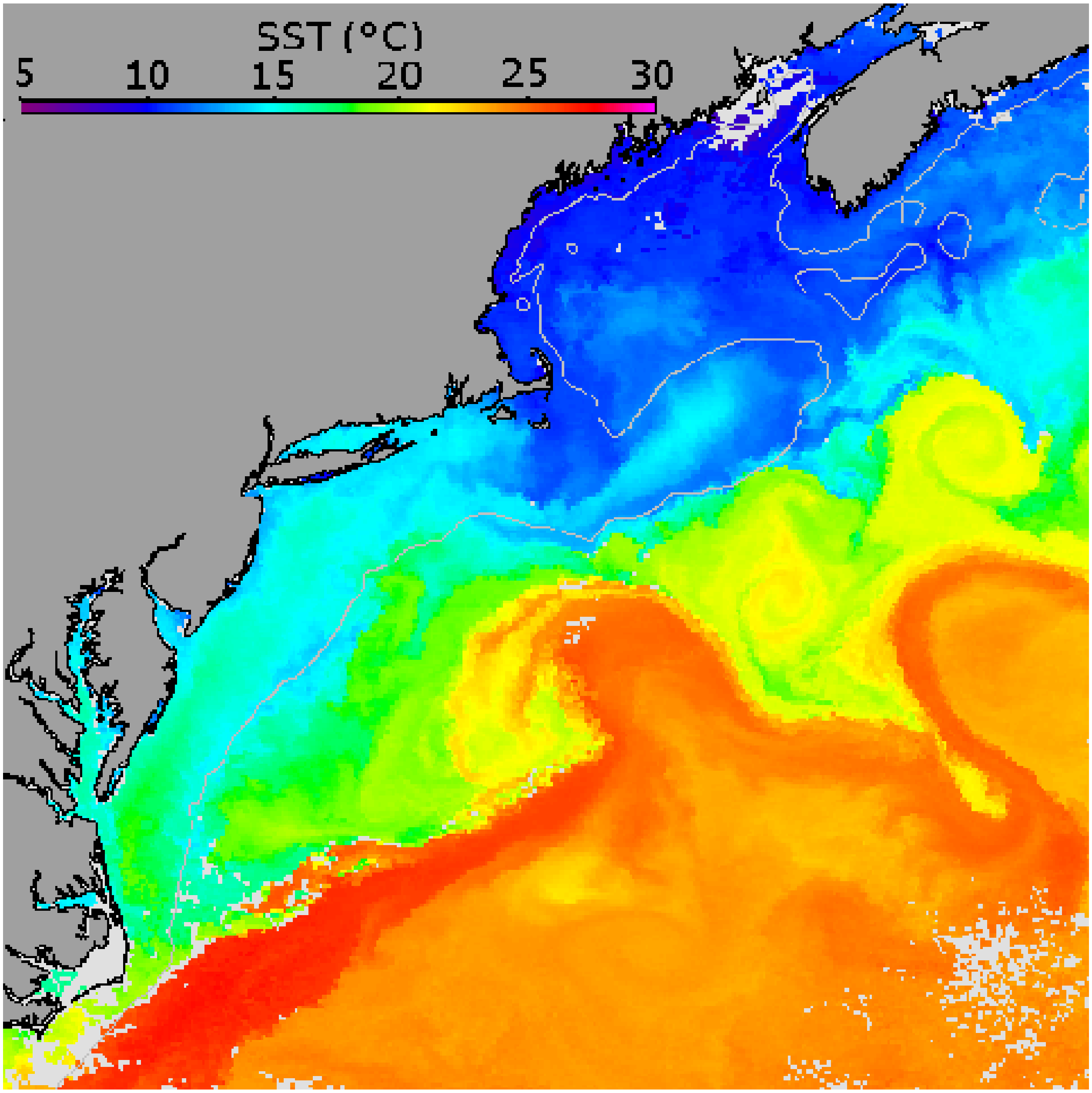
10.3 Climate Considerations

Climate and weather patterns over the North Atlantic are strongly influenced by the relative strengths of two large-scale atmospheric pressure cells - the Icelandic Low and the Bermuda-Azores high pressure system. A deepening of the Icelandic Low is typically accompanied by a strengthening of the Azores High and vice versa. This characteristic pattern is called the North Atlantic Oscillation (NAO) and a simple index of its state is given by the difference in sea level pressure in the vicinity of the Azores and Iceland in winter (December- February). When the NAO index is positive, we see a northward shift and increase in westerly winds, and an increase in precipitation over southeastern Canada, the eastern seaboard of the United States, and northwestern Europe. We also see increased storm activity tracking toward Europe. Water temperatures are markedly lower off Labrador and northern Newfoundland, influencing the formation of Deep Labrador Slope water, and warmer off the United State. Conversely, when the NAO index is negative, we have a southward shift and decrease in westerly winds, decreased storminess, and drier conditions over southeastern, the eastern United States, and northwestern Europe. Water temperatures are warmer off Labrador and Newfoundland, but cooler off the eastern United States. These changes in the state of the North Atlantic Oscillation tend to persist over decadal time scales. Changes in winds, precipitation and temperature associated with the North Atlantic Oscillation can have far reaching effects on the oceanography of our region.

Over the last several decades, the NAO has primarily been in a positive state; however, we have experienced increased variability in the NAO over the last decade. We have generally experienced warm water temperatures during this period, particularly in nearshore areas. This temperature increase closely tracks the change in the NAO index.

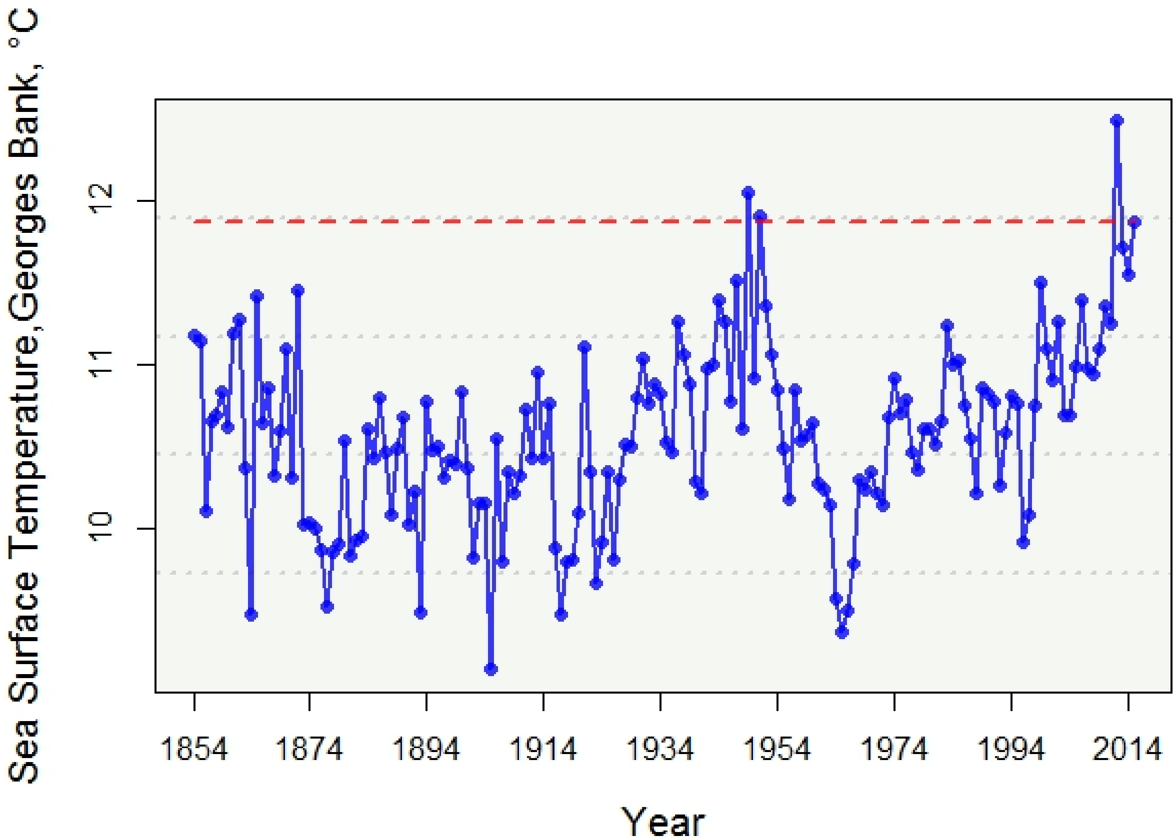
Temperature is one of the most important governing environmental factors for marine organisms. Marine organisms have minimum and maximum temperatures beyond which they cannot survive. Additionally, they have preferred temperature ranges and within these bounds, temperature influences many processes including metabolism, growth, consumption, and maturity. Thus, changes in temperature will have far-reaching impacts on species in the ecosystem and on the ecosystem itself. The NES LME experiences some of the highest amplitude changes in seasonal water temperatures on the planet. In addition, there are very large differences among the different regions of the shelf system (Map 6).

Map 6. Satellite image of fall surface water temperature patterns on the Northeast U.S. continental shelf. Cooler temperatures are represented by darker colors shading to blue. Warmer temperatures, such as those associated with the Gulf Stream are represented by the warmer colors shading to red.



Temperature in the NES LME has varied substantially over the past 150 years (Figure 16). The late 1800s and early 1900s were the coolest in the 150 year record. This relatively cool period was followed by a period of warm temperatures from 1945-1955. There was a rapid drop in temperatures through the 1960s followed by a steady increase to the present. Summer temperatures over the past 5 years are comparable to the warm period in the late-1940s/early 1950s and the summer 2012 surface temperature was the highest in the 158-year record. Winter temperatures in recent years, however, remain near the long-term mean indicating that the seasonal range in temperature has increased.

Figure 16. Long-term mean annual sea surface temperatures on Georges Bank from the ERSSTv3b dataset.

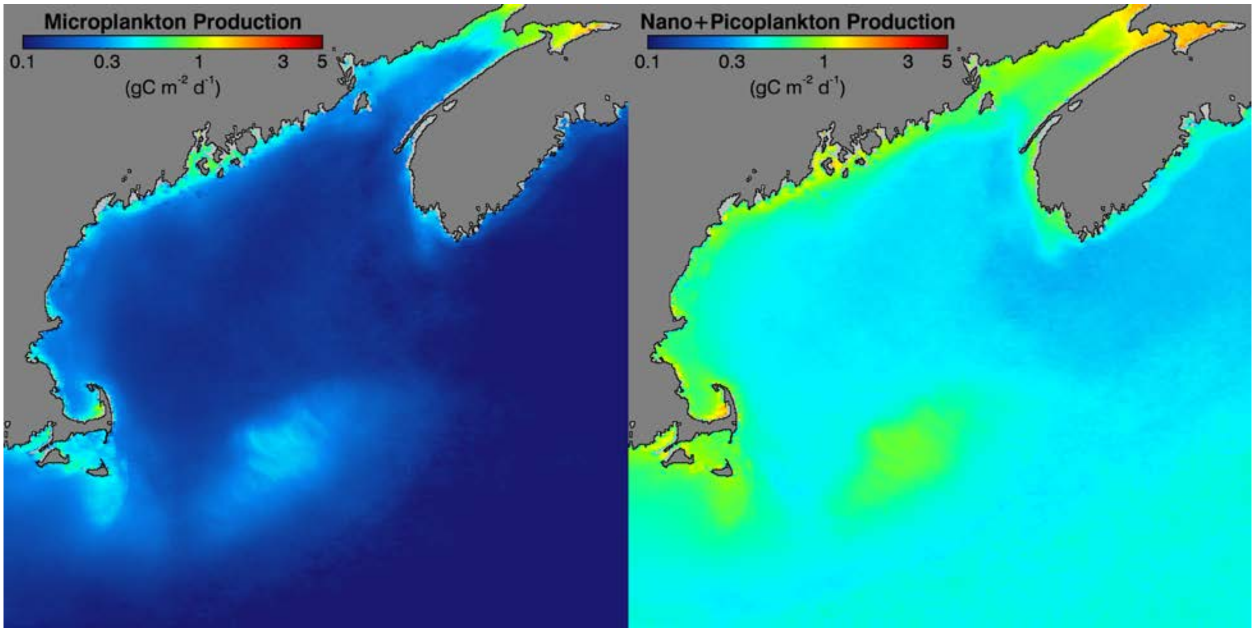


10.4 Production Characteristics

High levels of primary production on the bank have been linked to its unique topographic and hydrographic features (Mountain and Schlitz 1987). The circulation is characterized by an anticyclonic gyre driven by strong rotary tidal currents. The water over the shallow central plateau is well mixed and isothermal throughout the year, allowing nutrient regeneration and supporting high levels of primary production (Mountain and Schlitz 1987). Estimates of primary production as high as 450 $gC/m^2/yr$ have been reported for the central plateau of the bank (Cohen and Grosslein 1982, 1987). The circulation pattern provides a potential retention and transport mechanism on the bank with important implications for the survivorship of fish eggs and larvae (Bolz and Lough 1984; Smith and Morse 1984). Although Georges Bank is clearly an open system, characterized by import of secondary producers (e.g. *Calanus* from the Gulf of Maine and euphausids from deep water) and seasonal patterns of utilization by pelagic fish, marine mammal, sea turtle, and sea bird populations, it can legitimately be considered a distinct ecological system.

Satellite-derived estimates of primary production for two phytoplankton size classes, microphytoplankton (>20 μm) and nano-picophytoplankton (<20 μm) show important differences between production on Georges Bank relative on in the adjacent Gulf of Maine (Map 7). The central-basin of the Gulf of Maine is characterized by relatively low levels of primary production, although near-coastal regions have relatively high primary production levels fueled by nutrient inputs from land through river discharge. In contrast, Georges Bank exhibits high levels of primary production on the central crest of the bank for reasons described above. The microplankton production on the bank, comprising contributions from diatoms and larger dinoflagellates, is particularly dominant in spring when increasing sunlight and the renewal of nutrients to the upper water column during winter and spring due to oceanographic mixing processes provides the conditions necessary for the spring bloom. Many economically important species depend on the spring phytoplankton bloom and its consequent effect on zooplankton production for the survival of their larvae. The primary production attributable to nano- and pico-plankton in contrast is principally derived from recycled nutrients rather than the 'new' production by microplankton.

Map 7. Annual mean primary production (gC m-2d-1) from microplankton (left) and nano-picoplankton (right)

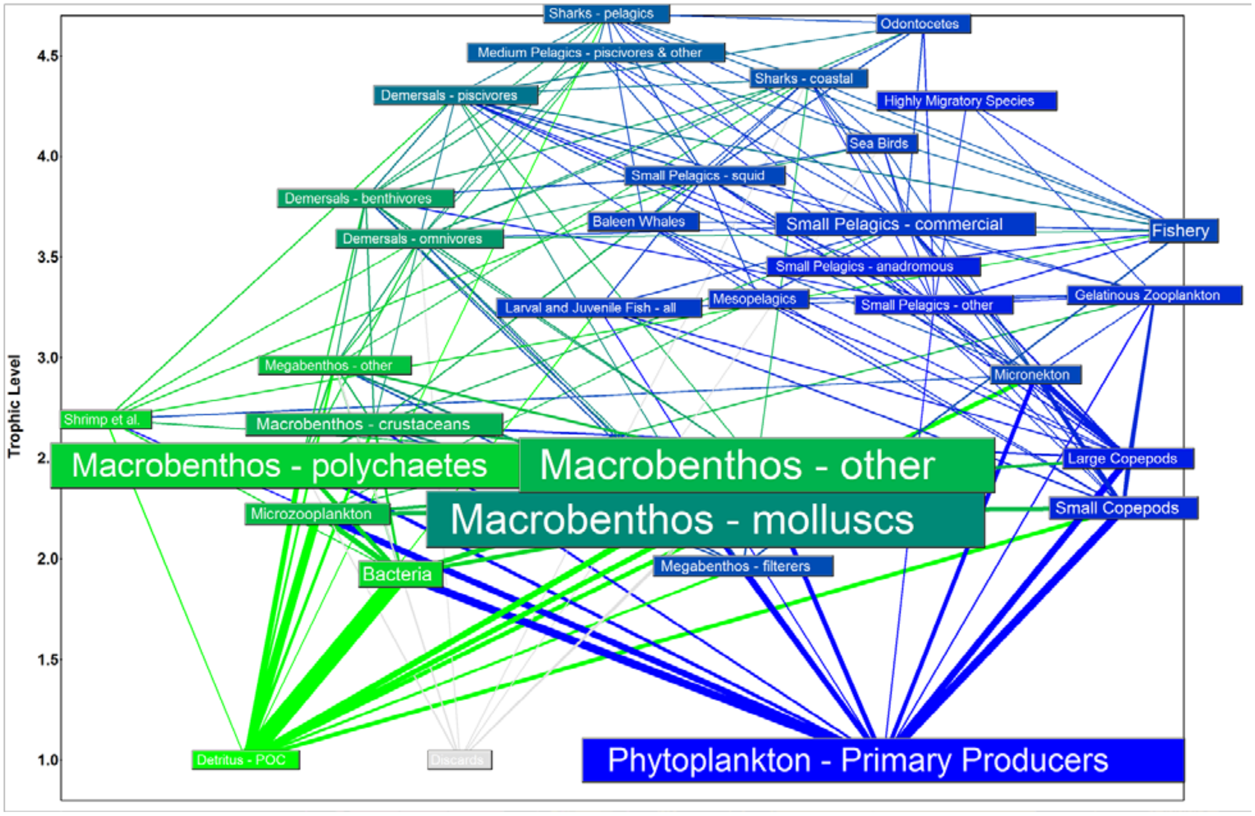


10.5 Georges Bank Food Web

System energetics has been extensively studied on Georges Bank (Cohen et al. 1982; Sissenwine et al. 1984; Sissenwine 1986; Cohen and Grosslein 1987). It has been inferred that production in this region is tightly bound, with most of the production of fish being consumed by other fish species (Sissenwine et al. 1984). These apparent energetic constraints can result in relatively stable levels of overall biomass and production of fish, although dramatic fluctuations at the individual species level are routinely observed. These characteristics suggest that perturbations induced by harvesting could have cascading effects through the system as top predators are removed and energetic constraints on other components of the systems are reduced.

A depiction of the Georges Bank food web used in a recent energy budget modeling exercise (Link et al. 2008) is provided in Figure 17. As is typical in these exercises, aggregated species groups are employed as nodes in the energy flow model. We will return to the application of mass-balance ecosystem models in Section 8.0 in the context of a broader discussion of ecosystem models for management.

Figure 17. Depiction of Georges Bank food web employed in the Link et al. (2008).



10.6 Forage Species in the New England Ecosystem(s)

A diverse assemblage of shelf and coastal fishes and squids can be categorized as forage species in the New England region (Table 8) according to the MAFMC 2012 Forage Species definition (Table 9). The Atlantic menhaden supports the single largest fishery on the U.S. east coast by weight and is managed by ASMFC. The Atlantic herring is managed jointly by the New England Fishery Management Council and ASMFC. Blueback herring and alewife fisheries, which have declined dramatically in the past 50 years and are under moratoria or greatly restricted landings in most coastal States, are managed jointly by the States and ASMFC. Atlantic mackerel, butterfish, and the longfin and *Illex* squids are managed by the MAFMC under a single FMP. Several taxa of small fishes that are not targeted in directed fisheries and are unmanaged, but are important as forage, occur in the coastal and shelf waters of the New England region (see Appendix A for a brief synopsis of each species). While not targeted currently in New England fisheries, some (e.g., the Alosines) once supported substantial fisheries in the coastal zone. Some of the unmanaged forage species may be included in bycatches of targeted fisheries, for example Alosines (river herrings) in the Atlantic herring and Atlantic mackerel fisheries. At present, there are no declared proposals or plans to exploit the unfished forage species listed here.

A broader characterization of the forage base in the GB EPU used predator diets to determine which species or groups are consumed by many predators, as well as which species are important to different types of predators and in different habitats. Diet and consumption data of varying quality are described in detail in Appendix B.

Table 8. Ranking of important forage species groups by predator type (highest frequency and/or consumption are first on the list).

Fish	Marine mammals	Sea Turtles	Seabirds

All in NEFSC database, including MAFMC managed
Crabs and shrimp
Amphipods
  Other zooplankton
Fish (incl. unid.)
Anchovies
  Hakes
Sand lance
Herrings
Molluscs
  Unid. cephalopods
  Longfin squid
  Bivalves
Annelids
Ctenophores
	Baleen Whales
	Krill
	Herrings
	Other zooplankton
	Sand lance
	Large gadids
	Mackerels
	Other fish
		Crabs
		Fish (scavenged?)
		Ctenophores and jellyfish
			Pelagic/coastal *Gulls:* fish, offal and fish scavenged from commercial fishing operations, euphausiids
			Shearwaters: fish (sand lance, saury), squids
			Storm petrels and Phalaropes: zooplankton, fish eggs and larvae
			Gannets: fish (menhaden, mackerel, saury
			Fulmars: euphausiids, squids

All in NEAMAP database
Crabs and shrimp
Fish (incl. unid)
  Anchovies
  Butterfish
  Sand lances
  Scup
  Menhaden
  Drums
Amphipods
Polychaetes
Molluscs
  Bivalves
  Longfin squid
Mysids
	Toothed Whales and Dolphins
	Squids
	Mackerels
	Other fish
	Small gadids
	Herrings
	Mesopelagics		

Highly Migratory *Large coastal sharks:* Fish (unid, bluefish, summer flounder) Skates/rays/sharks Crabs *Large pelagics:* Squids (incl. Illex sp.) Fish (unid, mackerel, butterfish, bluefish, hakes, sand lance)	**Seals** Other fish Sand lance Small gadids Flatfish Herrings Large gadids Squids	**ESA listed fish (sturgeons)** Annelids Shrimp Other benthic invertebrates	**Coastal** Fish and crustaceans; extremely varied diet along salinity gradients Osprey, Cormorants and Pelicans—Menhaden, herring, estuarine fish (mullet, drums, anchovy…)

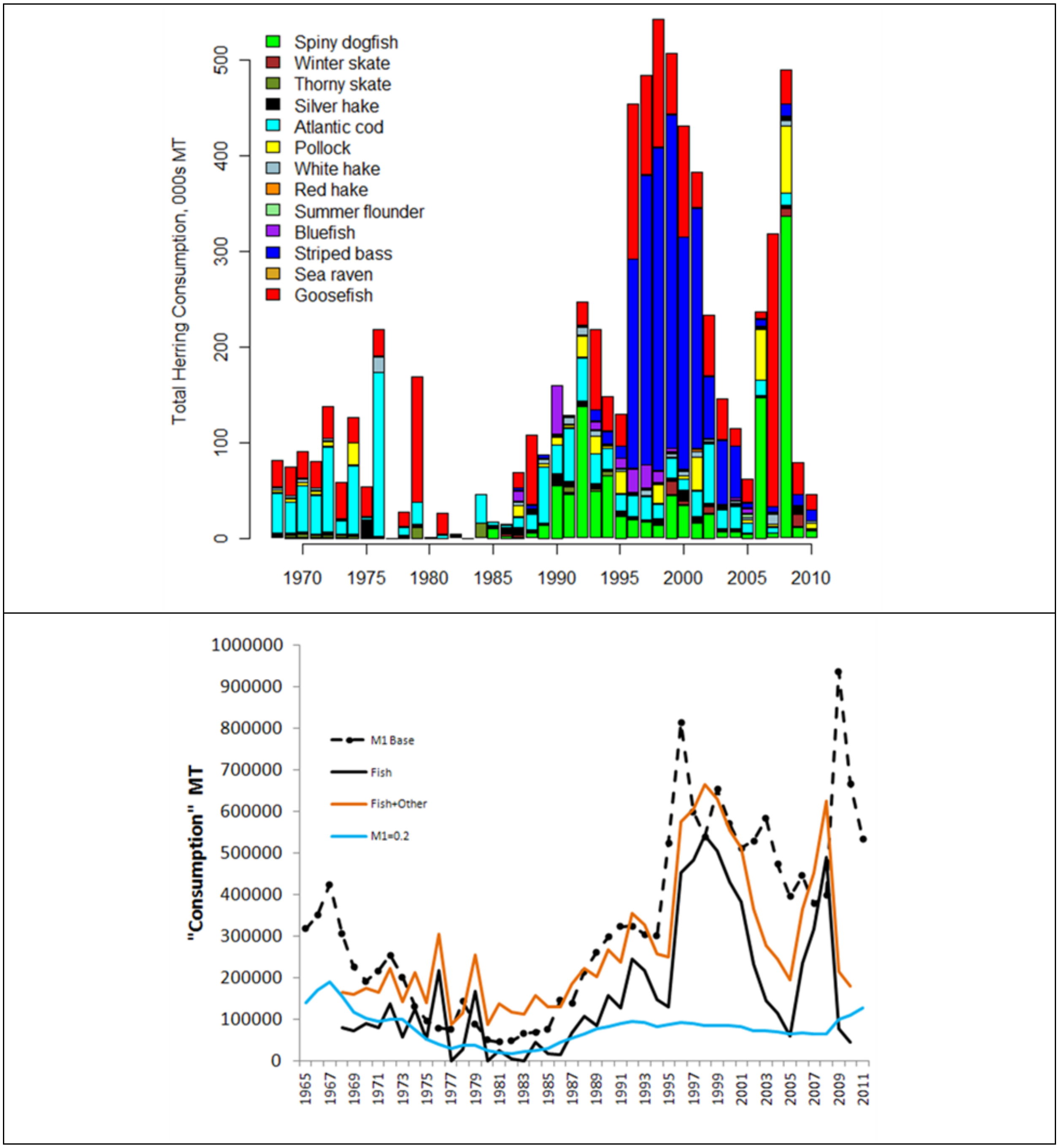
Table 9. Predator species in New England used to derive lists of forage species. Fish are listed in descending order of representation in the NEFSC database by number of collection locations, 1973-2012. Only relatively common predators in the New England region are listed in other categories.

Fish	Marine mammals	Sea Turtles	Seabirds
NEFMC managed Spiny dogfish Monkfish Little skate Spotted hake Silver hake Windowpane Atlantic herring Winter skate Red hake Winter Flounder Yellowtail flounder Witch flounder Clearnose skate Rosette skate	**Baleen Whales** Fin whale Humpback whale Sei whale Minke whale N Atlantic right whale	Loggerhead Leatherback Kemp's ridley	**Pelagic (shelf unless noted)** (spring, fall, winter) Herring gull Great black-backed gull Laughing gull (spring, summer, fall) Bonaparte's gull (spring) Black-legged kittiwake (spring, winter) (spring, shelf break) Red phalarope Red-necked phalarope (spring, winter) Northern gannet Northern fulmar (summer, shelf break) Wilson's storm-petrel Leach's storm-petrel (summer, fall) Great shearwater Cory's shearwater Manx shearwater Audubon's shearwater Sooty shearwater Common tern (spring) Royal tern (summer, fall, nearshore) Razorbill (winter, spring)
Other managed Summer flounder Butterfish Scup Atl. mackerel Bluefish Black sea bass Tilefish Fourspot flounder Smooth dogfish Weakfish Ocean pout Blueback herring N. Searobin Spot Atlantic croaker Gulf Stream flounder Sea raven Cusk eel Longhorn sculpin Striped bass American shad	**Toothed Whales and Dolphins** Pilot whale White-sided dolphin Common dolphin Bottlenose dolphin Harbor porpoise **Seals** Harbor seal Gray seal		**Coastal** Great cormorant Double-crested cormorant Loons Brown pelican American bittern Great blue-heron Snowy egret Great egret Tricolored heron Little blue heron Green heron Black-crowned Night-heron Common merganser Red-breasted merganser Osprey Black skimmer Bald eagle
Highly Migratory Large coastal sharks Pelagic sharks Billfish Tunas			
ESA listed Atlantic sturgeon Shortnose sturgeon			

Food habits information provides a picture of key forage for important New England commercial fish as well. We present estimated diet compositions for the top three predators of Atlantic herring over the past 40 years according to food habits data: spiny dogfish, Atlantic cod, and silver hake (Figure 18). Atlantic herring consumption estimates as presented in the 2012 assessment also give context for potential management as forage fish (Figure 19).

Figure 18. Estimated diet from Gulf of Maine, Georges Bank, and Southern New England combined for a) Spiny dogfish, b) Atlantic cod, c) silver hake; NEFSC diet database 1973-2012.

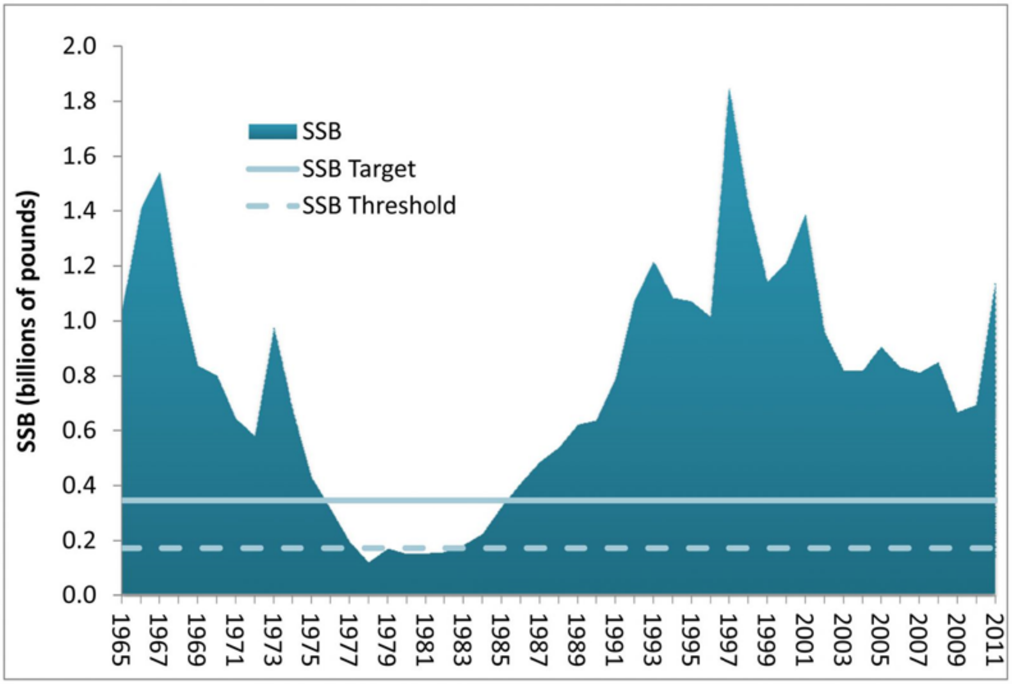
Figure 19. Consumption estimates of Atlantic herring, 2012 benchmark stock assessment.



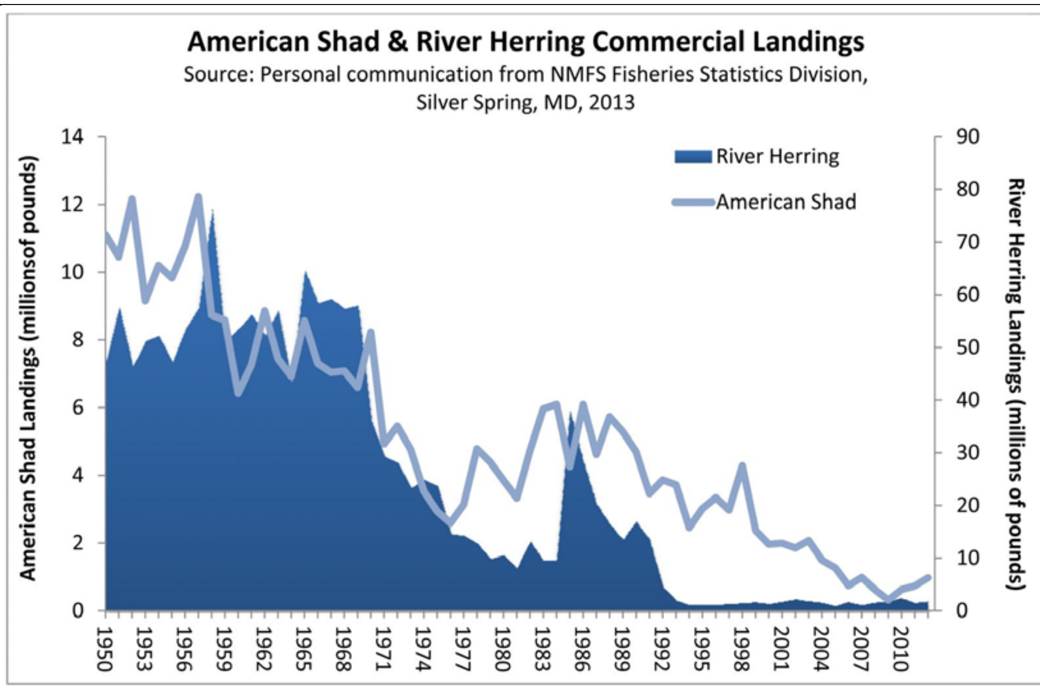
The past and present abundance of NEFMC managed forage species and other important forage species in the region can be partially reconstructed from stock assessments (Figure 20). However, methods applied differ across stock assessments, and not all assessments have been accepted for use in management (e.g., Atlantic mackerel, squids) so those assessments are not included here.

Managed forage abundance trends are mixed. Atlantic herring are abundant at present after recovering from low levels in the late 1970s, while American shad and river herring abundance is currently near an all time low coastwide.

Figure 20. Assessment results or landings trends for major forage fish in New England.



Atlantic Herring Spawning Stock Biomass (SSB). Source: 54th Northeast Regional Stock Assessment Workshop, 2012



The Gulf of Maine and Georges Bank food webs have been characterized quantitatively using the information sources listed above and many others (Link et al. 2006, Link et al. 2008). An updated set of food web models for the region is currently in development at NEFSC. Many studies exist in the literature where food web models were used to evaluate the impacts of severe overfishing of forage fish. However, it is rarer to find analyses of more subtle changes in forage management for populations that are not currently overfished, and analyses examining the implications for the ecosystem and predators when some forage species are depleted but others are abundant. Therefore, model analyses more tailored to the New England region and the suites of forage and predator species of varying status would be necessary to evaluate the potential effects of alternative management actions here.

10.6.1 Assessing the forage base in the New England region

A multi-faceted approach is necessary to assess the status of the forage base in aggregate. Simply put, total forage species production is constrained by the amount of primary production in the ecosystem, and total predator demand for forage species is based on consumption rates combined with the total biomass of predators. Predator demand plus fishing removals cannot exceed forage species production in aggregate or forage species biomass will decline. Estimates of primary production can be used to determine the potential forage species production in an ecosystem. Food web models can be used to estimate aggregate predator consumption demand. Food web models can also simulate ecosystem responses to changes in forage fish production, consumption, and/or fishery removals. These models can also be linked to economic models to determine how ecosystem responses alter economic relationships. For example, Fay et al. (2014) recently coupled an economic input/output model, capable of estimating short-term impacts of policy changes, to the Northeast United States Atlantis ecosystem model. Although not estimating economic value, this type of model coupling can provide an understanding of employment, income, and sales impacts the regional economy is likely to face due to changes in fishery management strategies.

A suite of ecosystem indicators can also be developed to monitor and assess the status of the aggregate forage base. Food web and multispecies models can help aggregate time series of abundance for multiple forage fish to estimate aggregate forage biomass. In addition, indices of primary production can be monitored to evaluate the production available for forage species, and condition factor of predatory fish, and reproductive success of seabirds, marine mammals, and other unexploited predators can be monitored to evaluate whether consumption needs are being met. Multiple metrics must be monitored together because any one of these could be driven by something other than forage fish status. Many of these indicators already exist for the New England region and are presented in the Ecosystem Status Report (NEFSC 2011); further development of an aggregate forage base status indicator is ongoing. This development will continue with the input of NEFMC.

10.6.2 Communities and fleets landing Herring

This section describes the importance of Atlantic herring as a primary forage species in the New England region (i.e. not solely focused on the Georges Bank EPU). The following discussion is an abridged version of the recent community assessment in Herring Amendment 8 (NEFMC 2019), Section 3.6.3, where more details may be found.

10.6.2.1 Directed fishing

There are over 150 communities that have been a homeport or landing port to one or more active Atlantic herring fishing vessels since 1997. These ports mostly occur from Maine to New Jersey. The level of activity in the herring fishery has varied across time. While the involvement of communities in the

Atlantic herring fishery is described, it is important to remember that the involvement of vessels therein may vary.

There are 17 primary ports for the Atlantic herring fishery. During the period 2007-2016, Atlantic herring was landed in over eight states. Most landings occurred in Maine (82M lbs. (37K mt)/year) and Massachusetts (79M lbs. (36K mt)/year; Table 10). Within these states, Atlantic herring was landed in 130 ports. Gloucester and Portland have been the top two landing ports during this time.

There are 17 primary ports for the Atlantic herring fishery, meeting one or more of these criteria (Table 10). For Criterion #4, as there are well over 5,000 vessels landing lobster in ports from Maine to Virginia, a subset of representative ports is included here. Herring is used as bait primarily in ports from Maine to Massachusetts. Ports with landings over 10M lbs (4,536 mt) each year from 1997-2008, a criterion in Amendment 5, is included for comparison purposes.

Table 10. Annualized Atlantic herring landings to states and primary ports, 2007-2016.

State/Port	Top port ranking	2007-2016 Avg. landings (mt)	Herring permits [a]	Herring dealers [a]
Maine		37,278	62	103
Portland	#2	16,986	33	80
Rockland	#4	13,319	20	67
Stonington	#6	2,359	12	33
Vinalhaven	#10	928	8	7
Jonesport	#12	763	8	13
S. Bristol	#19	231	6	4
Other (n=35)*		2,692	39	72
New Hampshire		829	26	32
Massachusetts		35,988	66	97
Gloucester	#1	19,892	39	83
New Bedford	#3	14,694	28	63
Other (n=11)		1,402	29	45
Rhode Island		5,326	58	35
Point Judith	#5	3,227	171	29
Newport	#13	612	12	8
Other (n=8)		1,487	9	7
Connecticut		6	11	6
New York		40	73	30
Montauk	#39	10	45	16
Hampton Bays/ Shinnecock	#37	13	29	16
Other (n=12)		17	14	13
New Jersey		2,150	56	12
Maryland		5	11	3
Confidential state(s)		307	9	7
Total	**130**	**81,930**	**291**	**190**

[a] Totals may not equal the sum of the parts, because permits can land in multiple ports/states.
*Prospect Harbor, Maine is the ninth port for landings during this time (12Kmt total), but it is not a primary port.
Source: Dealer data, accessed July 2017.

10.6.2.2 Indirect importance to other fisheries and ecotourism

Summarized below are the key port communities that are important to each of these fisheries, as identified by the lead management entity for each. Where the management entity has not previously identified the relevant communities, a method was developed through this action and explained below. Many ports have coexisting fisheries, including the Atlantic herring fishery. In all, about 140 communities have been identified as potentially impacted (Table 12).

Atlantic Mackerel: Many vessels that participate in the Atlantic herring fishery are also active in the Atlantic mackerel fishery. Primary ports identified in the Mackerel, Squid, Butterfish FMP had at least

$100,000 in ex-vessel revenues from mackerel during 2012-2014 (combined) included (from more mackerel dollars to less): North Kingstown, RI; Gloucester, MA; New Bedford, MA; Portland, ME; Cape May, NJ; Marshfield, MA; Provincetown, MA; and Point Judith, RI (Table 12) (MAFMC 2016b). For purposes of this action, these are considered the primary mackerel ports. There are 11 other ports that are either a homeport or a primary landing port for ≥1 Atlantic mackerel vessel(s) (MAFMC 2015), and these are considered secondary ports here.

American Lobster: The American lobster fishery is the primary end user of Atlantic herring as bait. American lobster is landed in many port communities on the Atlantic coast. The ASMFC does not identify key ports in the FMP for this fishery. In 2015, 18 of the top 20 ports for lobster landed value were in Maine (primarily midcoast to eastern Maine), and two were in Massachusetts (Table 77). For purposes of this action, these 20 top ports are considered the primary lobster ports. In 2015, there were also 2,297 federal lobster licenses issued to vessels from 279 home ports (15 states) and 273 primary landing ports (12 states). Of these, there were 63 ports that were either the home port or primary landing port to at least 10 federal lobster vessels (Table 11), and these are considered secondary ports here. Since about 8,000 state waters-only lobster licenses are issued annually, many more ports likely have over 10 lobster licenses issued per port.

Bluefin Tuna: Atlantic herring is important to tuna as a prey item in the ecosystem as well as a bait source for a subset of the fishery. NMFS has identified 28 fishing communities important to the Highly Migratory Species fishery (including 53 species of tunas, swordfish, sharks, etc.) defined by the proportion of HMS landings in the town, the relationship between the geographic communities and the fishing fleets, socioeconomic research, community studies, and input from advisory bodies. The communities in Maine to New Jersey are: Gloucester and New Bedford, MA; Wakefield RI; Montauk, NY; and Brielle, Barnegat Light, and Cape May, NJ (NMFS 2011b). For purposes of this action, these 7 top ports are considered the primary tuna ports (Table 12). As of October 2017, there were 6,620 current tuna permits issued (GARFO 2017), 4,009 (61%) of which were in states from Maine to New Jersey. Within these states, 82 communities have ≥10 bluefin tuna vessels as its principal port, and these are considered secondary ports here.

Commercial Groundfish: Atlantic herring is important to groundfish as a prey item in the ecosystem as well; it is a bait source for a very minor subset of the commercial fishery (more important for recreational bait). There are over 400 communities that have been the homeport or landing port to one or more commercial Northeast groundfish fishing vessels since 2008. Of these, 10 ports have been identified as primary commercial groundfish port communities (and 22 secondary ports), based on the level of commercial groundfish activity in the port (Table 12). Primary ports have, during FY 2009-FY 2013, at least $100,000 average annual revenue (for all species, not just groundfish) and are in the top ten ranking in regional quotient or local quotient (confidential ports excluded). For purposes of this action, these 10 top ports are considered the primary commercial groundfish ports. Secondary ports are in the top 11-30 ranking in regional or local quotient (same revenue threshold; NEFMC 2017).

Table 11. Top 20 landing ports by lobster revenue, 2015, Maine to New Jersey

State	Port	Top 20 landing port for lobster revenue		
		Revenue	# of vessels	# of dealers
ME	Jonesport	$9.8M	178	6
	Beals	$20M	234	5
	Milbridge	$11M	76	13
	Steuben	$9.4M	71	11
	Winter Harbor	$8.4M	39	3
	Southwest Harbor	$11M	109	8
	Bass Harbor	$11M	91	7
	Swans Island	$11M	93	4
	Stonington	$62M	367	10
	Rockland	$13M	163	4
	Vinalhaven	$39M	222	12
	Owls Head	$10M	71	4
	S. Thomaston/Spruce Head	$17M	130	10
	Port Clyde	$10M	103	10
	Tenants Harbor	$9.7M	92	11
	Cushing	$9.1M	68	9
	Friendship	$21M	165	10
	Portland	$17M	230	21
MA	Gloucester	$16M	202	24
	New Bedford/Fairhaven	$8.3M	91	22
Source: ACCSP, Aug.2017				

Recreational: Atlantic herring is important to recreational fisheries as a prey item in the ecosystem as well as a bait source for a subset of the fishery. The relevant recreational fisheries are primarily tuna, striped bass, and groundfish. In the fishery management plans for these fisheries, criteria for identifying key recreational fishing communities have not been identified. For this action, a community is considered a recreational fishing community"

- If the community has a high level of engagement or reliance in recreational fishing using the NMFS Community Vulnerability Indicators, which portray the importance or level of dependence on recreational fishing by coastal communities (Jepson & Colburn 2013). The engagement index incorporates the number of recreational fishing trips in 2011-2015 by fishing mode (private boat, charter boat, shore fishing) originating in the community (using MRIP data). The reliance index is a per capita measure using the same data as the engagement index but divided by total population in the community.
- Located on or near the coast in a coastal state from Maine to New Jersey. These are the states adjacent to the Atlantic herring stock area.

From 2011 to 2015, there were 191 fishing communities from Maine to New Jersey identified as the principal port for the 571 vessels with Northeast multispecies charter/party permits (Category I). Montauk, NY had the most permits (annual average of 52). There were 12 ports with an annual average of ten or more permits that also met the above criteria. For this action, these are considered the primary recreational communities (Table 12), others are considered secondary ports.

Ecotourism: The Friends of the Maine Coastal Island National Wildlife Refuge lists several seabird watching businesses, 11 Maine communities. GARFO indicates there are 17 whale watching businesses from Maine to New Jersey (Section 3.6.2.7 in NEFMC 2019; Table 12).

Table 12. Ports with a high recreational fishing community engagement or reliance indicator and number of party/charter permits on average in 2011-2015 (if ≥10)

State	Community	Community Index		# of vessels with party/charter permits
		Engagement	Reliance	
ME	Biddeford	High	Low	
NH	Hampton	High	Medium	12
	Seabrook	High	Medium	
MA	Salisbury	High	Med-High	
	Newburyport	High	Medium	11
	Gloucester	High	Medium	20
	Plymouth	High	Low	11
	Marshfield (Green Harbor-Cedar Crest/ Marshfield Hills/Ocean Bluff-Brant Rock)	High	Medium	27
	Sandwich (E. Sandwich/Forestdale)	High	Medium	
	Barnstable	High	Medium	
	Yarmouth (S. Yarmouth/W. Yarmouth/ Yarmouth Port)	High	Low	
	Dennis	High	High	
	Chatham	Med-High	High	
	Harwich Port	Med-High	High	
	Falmouth	High	High	
	Bourne	High	High	
	Wareham (W. Wareham/Onset)	High	Low	
	Nantucket	High	Med-High	
	Westport	High	Medium	
RI	Tiverton	High	Low	
	Bristol	High	Low	
	Jamestown	High	Medium	
	Warwick	High	Low	
	Narragansett (Point Judith)	High	Med-High	22
	S. Kingstown (Kingston/Wakefield-Peacedale)	High	Low	
	Charlestown (Carolina)	High	Medium	
CT	Stonington (Mystic/Pawcatuck)	High	Medium	
	Groton	High	Medium	
	Waterford	High	Medium	
	East Lyme (Niantic)	High	Medium	
	Old Lyme	High	Medium	
	Old Saybrook	High	Med-High	

State	Community	Community Index		# of vessels with party/charter permits
		Engagement	Reliance	
	Milford	High	Low	
NY	Northport	High	Medium	
	Port Jefferson	High	Medium	
	Mt. Sinai	High	Medium	
	Moriches	High	High	
	Shirley	High	Low	
	Mastic Beach	High	Low	
	Orient	High	High	
	Montauk	High	High	52
	Hampton Bays	High	High	
	Babylon	High	High	
	Oak Beach-Captree	Low	High	
	Wantagh	High	Medium	
	Point Lookout	High	High	
	Long Beach	High	Low	
	Brooklyn (Sheepshead Bay)	High	Low	12
	Queens	High	Low	
NJ	Keyport	High	Med-High	
	N. Middletown	High	Medium	
	Port Monmouth	High	Medium	
	Leonardo	High	High	
	Atlantic Highlands	High	High	
	Belmar (South Belmar)	High	High	15
	Manasquan	High	Medium	
	Brielle	High	Med-High	
	Pt. Pleasant	High	Med-High	15
	Berkeley (Bayville)	High	Low	
	Barnegat Light	High	High	10
	Port Republic	Med-High	High	
	Brigantine	High	Medium	
	Abesecon	High	Medium	
	Margate City	High	Med-High	
	Somers Point	High	Medium	
	Ocean City	High	Medium	
	Sea Isle City	High	High	
	Stone Harbor	High	High	
	Wildwood	High	High	
	Lower (Erma/North Cape May/Villas)	High	Low	
	Cape May	High	High	29
	Maurice River (Leesburg)	High	Medium	
	Downe (Fortesque)/Newport	High	High	

10.7 Historical Fishing Patterns

The Georges Bank region has supported important commercial fisheries since the 16th century (German 1987; Murawski, MS). Although sharp declines in abundance had been noted prior to the turn of the 20th century for some exploited species, most notably Atlantic halibut, sustainable fisheries were prosecuted for a broad suite of pelagic and demersal fish species. Sail-powered vessels, employing passive fishing gears such as long-lines, were used in prosecution of the fishery during most of its history. The advent of mechanized trawling during the early decades of this century altered both the character of the fisheries and the potential to reduce the abundance and productivity of these resources (Hennemuth and Rockwell 1987; Murawski, MS). Later technological innovations in vessel design and construction (e.g. introduction of steel hull stern trawlers) and electronics (RADAR, LORAN, GPS and advanced echosounders) have further enhanced the efficiency of operations and the impact on the resource, far outstripping its capacity to withstand exploitation without direct controls.

Georges Bank has been subjected to major perturbations within the last four decades which have profoundly altered levels of catch, abundance, and species composition. The arrival of distant water fleets during the early 1960's resulted in dramatic increases in effective fishing effort and the subsequent commercial collapse of several fish populations. Total fish biomass is estimated to have declined by over 50% on Georges Bank during the period of operation of the distant water fleets. The implementation of extended jurisdiction (the 200 mile limit) in 1977 was followed by modernization and increased capacity of the domestic fleet, resulting in a second perturbation to the system which resulted in further declines in groundfish populations to historically low levels. A concomitant increase in the abundance of species of low commercial value was documented, with an apparent replacement of gadid and flounder species by small elasmobranchs (including dogfish sharks and skates). Examination of feeding guild structure suggests that this switch in species dominance may be linked to a competitive release. The small elasmobranchs, notably dogfish sharks, also prey on species of commercial importance (primarily small pelagics including herring and mackerel). The cumulative impacts on the groundfish populations as a result of intense exploitation and predation pressure may be further exacerbated by impacts of fishing gear on the physical structure of the habitat.

10.8 Summary of characteristics and management authority of species with the Georges Bank EPU

Table 13. Biological and trophic characteristics of Georges Bank EPU species.

Species	*Scientific Name*	Management authority	FMP	Total q-adjusted biomass	Species Complex	Trophic level	Adult body size	Primary Offshore Habitat	Preferred Depth Range (m)
1. Yellowfin Tuna	*Thunnus albacares*	NMFS-SFD	HMS	#N/A	Apex Predator			Pelagic	
2. Bluefin Tuna	*Thunnus thynnus*	NMFS-SFD	HMS	#N/A	Apex Predator			Pelagic	
3. Swordfish	*Xiphias gladius*	NMFS-SFD	HMS	#N/A	Apex Predator			Pelagic	
4. Other Skarks		ASMFC	Coastal Sharks	#N/A	Apex Predator			Pelagic	
5. Atlantic Wolffish	*Anarhicas lupus*	NEFMC	NE Multispecies	0.15	Benthivore	3.2	150	Sand and gravel, spawn in rocky habitats	70-184
6. Channel Whelk	*Busycon*	Unmanaged	NA	#N/A	Benthivore				
7. Blue Crab	*Callinectes sapidus*	Unmanaged	NA	#N/A	Benthivore				
8. Jonah Crab	*Cancer borealis*	ASMFC	Jonah Crab	0.32	Benthivore				
9. Cancer Crabs	*Cancer spp.*	Unmanaged	NA	#N/A	Benthivore				
10. Black Sea Bass	*Centropristis striata*	MAFMC/ASMFC	Summer Flounder, Scup, and Black Sea Bass	0.25	Benthivore	4	66		
11. Red Crab	*Geryon quinquidens*	NEFMC	Red crab	#N/A	Benthivore	2.5		Silt and clay	320-1300
12. Witch Flounder	*Glyptocephalus cynoglossus*	NEFMC	NE Multispecies	0.13	Benthivore	3.1	60	Mud and muddy sand	80-400
13. American Plaice	*Hippoglossoides platessoides*	NEFMC	NE Multispecies	0.45	Benthivore	3.7	> 20	Mud and sand	40-300
14. American Lobster	*Homarus americanus*	ASMFC	Lobster	16.68	Benthivore				

Species	*Scientific Name*	Management authority	FMP	Total q-adjusted biomass	Species Complex	Trophic level	Adult body size	Primary Offshore Habitat	Preferred Depth Range (m)
15. Rosette Skate	*Leucoraja garmani*	NEFMC	NE Skate Complex	0.07	Benthivore		26	Mud and sand	80-400
16. Yellowtail Flounder	*Limanda ferruginea*	NEFMC	NE Multispecies	1.61	Benthivore	3.2	64	Sand with and w/o shells, gravel, and rocksd	30-90
17. Golden Tilefish	*Lopholatilus chamaeleonticeps*	MAFMC	Tilefish	#N/A	Benthivore	3.5	125	Semi-consolidated clay	100-300
18. Haddock	*Melanogrammus aeglefinus*	NEFMC	NE Multispecies	938.76	Benthivore	4.1	112	Sand, shells, gravel, along margins of rocky reefs	40-160
19. Smooth Dogfish	*Mustelus canis*	ASMFC	Coastal Sharks	6.61	Benthivore	4.2	150	Pelagic	
20. Lady Crab	*Ovalipes oscillatus*	Unmanaged	NA	1.67	Benthivore				
21. Northern Searobin	*Prionotus carolinus*	Unmanaged	NA	0.75	Benthivore	4.2	38		
22. Striped Searobin	*Prionotus evolans*	Unmanaged	NA	#N/A	Benthivore	4.2	45		
23. Winter Flounder	*Pseudopleuronectes americanus*	NEFMC	NE Multispecies	8.96	Benthivore	2.8	64	Mud, sand, and hard bottom	10 to 70
24. Scup	*Stenotomus chrysops*	MAFMC/ASMFC	Summer Flounder, Scup, and Black Sea Bass	18.97	Benthivore	3.9	46	Sand, mud, mussel beds, rock and other structures	10 to 50
25. Tautog	*Tautoga onitis*	ASMFC	Tautog	#N/A	Benthivore	3.3	91		
26. Cunner	*Tautogolabrus adspersus*	Unmanaged	NA	1.17	Benthivore		38		
27. Ocean Pout	*Zoarces americanus*	NEFMC	NE Multispecies	1.08	Benthivore	3.4	110	Wide variety of substrates, esp in association with structure	20-140
28. Spider Crab		Unmanaged	NA	#N/A	Benthivore				
29. Octopus		Unmanaged	NA	#N/A	Benthivore				

Species	*Scientific Name*	Managemen t authority	FMP	Total q-adjusted biomass	Species Complex	Trophic level	Adult body size	Primary Offshore Habitat	Preferred Depth Range (m)
30. Conchs		Unmanaged	NA	#N/A	Benthivore				
31. Sea Urchin		Unmanaged	NA	#N/A	Benthivore				
32. Ocean Quahog	*Arctica islandica*	MAFMC	Surf Clam & Ocean Quohog	#N/A	Benthos			Mud, sand, gravel	40-100
33. Mussels	*Mytilus spp.*	Unmanaged	NA	#N/A	Benthos				
34. Sea Scallop (Live)	*Placopectin magellanicus*	NEFMC	Sea Scallop	37.44	Benthos	1.94		Sand and gravel	18-110
35. Surf clam (Live)	*Spisula solidissima*	MAFMC	Surf Clam & Ocean Quohog	0.03	Benthos	1.94		Sand and gravel	8 to 40
36. Sea Cucumber		Unmanaged	NA	#N/A	Benthos				
37. American Plaice	*Hippoglossoides platessoides*	NEFMC	NE Multispecies	0.45	Macroplanktivore	3.7	< 20	Mud and sand	40-300
38. Lumpfish	*Cyclopterus lumpus*	Unmanaged	NA	#N/A	Macroplanktivore	3.9	61		
39. Shortfin squid	*Illex illecebrosus*	MAFMC	Mackerel, Squid, and Butterfish	1.51	Macroplanktivore	3.33		Pelagic	70-400
40. Longfin Squid	*Loligo peleii*	MAFMC	Mackerel, Squid, and Butterfish	28.76	Macroplanktivore	3.4		Pelagic	30-200
41. Longhorn Sculpin	*Myoxocephalus octodecemspinosus*	NEFMC	NE Multispecies	5.21	Macroplanktivore	3.7	46		
42. Red Hake	*Urophycis chuss*	NEFMC	NE Small-mesh Multispecies	5.27	Macroplanktivore	3.6	< 40	Soft sediments and shells	50-300
43. Spiny Dogfish	*Squalus acanthias*	MAFMC/NE FMC	NE Skate Complex	192.42	Macroplanktivore	4.3	< 60		20-300
44. White Hake	*Urophycis tenuis*	NEFMC	NE Multispecies	0.15	Macroplanktivore	4.2	20 - 40	Fine sediments, mixed and rocky habitats	30-400

Species	*Scientific Name*	Management authority	FMP	Total q-adjusted biomass	Species Complex	Trophic level	Adult body size	Primary Offshore Habitat	Preferred Depth Range (m)
45. White Hake	*Urophycis tenuis*	NEFMC	NE Multispecies	0.15	Macroplanktivore	4.2	< 20	Fine sediments, mixed and rocky habitats	30-400
46. Cusk	*Brosme brosme*	Unmanaged	NA	#N/A	Macrozoo-piscivore	4	120	Gravel and rocky ground, boulders	100-200
47. Blackbelly Rosefish	*Heliolenus dactylopterus*	Unmanaged	NA	3.22	Macrozoo-piscivore		47		
48. Little Skate	*Leucoraja erinacea*	NEFMC	NE Skate Complex	68.01	Macrozoo-piscivore	3.6	54	Sand and gravel	10-100
49. Smooth Skate	*Malacoraja senta*	NEFMC	NE Skate Complex	0.05	Macrozoo-piscivore		61	Soft mud	100-400
50. Pollock	*Pollachius virens*	NEFMC	NE Multispecies	0.30	Macrozoo-piscivore	4.4	130	Over rocky substrates	80-300
51. Clearnose Skate	*Raja eglanteria*	NEFMC	NE Skate Complex	#N/A	Macrozoo-piscivore		84	Mud and sand	0-40
52. Windowpane	*Scophthalmus aquosus*	NEFMC	NE Multispecies	2.62	Macrozoo-piscivore		46	Mud and sand	0-70
53. Red Hake	*Urophycis chuss*	NEFMC	NE Small-mesh Multispecies	10.54	Macrozoo-piscivore	3.6	66	Soft sediments and shells	50-300
54. Offshore Hake	*Merluccius albidus*	NEFMC	NE Small-mesh Multispecies	0.04	Macrozoo-piscivore	4.3	< 40	?	160-500
55. Silver Hake	*Merluccius bilinearis*	NEFMC	NE Small-mesh Multispecies	9.74	Macrozoo-piscivore	4.3	< 40	Sand	40-400
56. Blueback Herring	*Alosa aestivalis*	ASMFC	Shad & River Herring	0.51	Mesoplanktivore		40	Pelagic	
57. Alewife	*Alosa pseudoharengus*	ASMFC	Shad & River Herring	1.03	Mesoplanktivore		40		
58. American Shad	*Alosa sapidissima*	ASMFC	Shad & River Herring	0.81	Mesoplanktivore		76		
59. Atlantic Menhaden	*Brevoortia tyrannus*	MAFMC	Atlantic Menhaden	#N/A	Mesoplanktivore		50	Pelagic	
60. Atlantic Herring	*Clupea harengus*	NEFMC/ASMFC	Herring	601.69	Mesoplanktivore	3.2	45	Pelagic	60-140
61. Thorny Skate	*Amblyraja radiata*	NEFMC	NE Skate Complex	0.06	Piscivore		105	Variety of habitats	70-400

Species	*Scientific Name*	Management authority	FMP	Total q-adjusted biomass	Species Complex	Trophic level	Adult body size	Primary Offshore Habitat	Preferred Depth Range (m)
62. Weakfish	*Cynoscion regalis*	ASMFC	Weakfish	#N/A	Piscivore	3.8	98	Pelagic	
63. Barndoor Skate	*Diptutus laevis*	NEFMC	NE Skate Complex	24.38	Piscivore		152	Mud, sand, and gravel	40-400
64. Atlantic Cod	*Gadus morhua*	NEFMC	NE Multispecies	15.59	Piscivore	4.4	200	Complex hard bottom habitats, sand and gravel	30-160
65. Sea Raven	*Hemitripterus americanus*	Unmanaged	NA	5.34	Piscivore		64		
66. Fourspot Flounder	*Hippoglossina oblonga*	Unmanaged	NA	4.69	Piscivore		41		
67. Atlantic Halibut	*Hippoglossus hippoglossus*	NEFMC	NE Multispecies	0.63	Piscivore	4.5	470	Sand, gravel, or clay	60-140, also on slope
68. Winter Skate	*Leucoraja ocellata*	NEFMC	NE Skate Complex	146.56	Piscivore		110	Sand and gravel	10 to 90
69. Goosefish	*Lophius americanus*	NEFMC/MAFMC	Monkfish	1.24	Piscivore	4.45	120	Variety of habitats, prefer soft sediments	50-400
70. Offshore Hake	*Merluccius albidus*	NEFMC	NE Small-mesh Multispecies	0.09	Piscivore	4.3	41	?	160-500
71. Silver Hake	*Merluccius bilinearis*	NEFMC	NE Small-mesh Multispecies	19.49	Piscivore	4.3	76	Sand	40-400
72. Striped Bass	*Morone saxatilis*	ASMFC	Striped Bass	0.33	Piscivore	4.5	200	Pelagic	
73. Summer Flounder	*Paralichthys dentatus*	MAFMC/ASMFC	Summer Flounder, Scup, and Black Sea Bass	4.69	Piscivore	4.5	94		
74. Bluefish	*Pomatomus saltatrix*	MAFMC	Bluefish	5.63	Piscivore	4.5	130	Pelagic	10 to 50
75. Spiny Dogfish	*Squalus acanthias*	MAFMC/NEFMC	NE Skate Complex	192.42	Piscivore	4.3	40-160		20-300
76. White Hake	*Urophycis tenuis*	NEFMC	NE Multispecies	0.46	Piscivore	4.2	133	Fine sediments, mixed and rocky habitats	30-400
77. Butterfish	*Peprilus triacanthus*	MAFMC	Mackerel, Squid, and Butterfish	11.47	Planktivore	4	30	Pelagic	

Species	*Scientific Name*	Management authority	FMP	Total q-adjusted biomass	Species Complex	Trophic level	Adult body size	Primary Offshore Habitat	Preferred Depth Range (m)
78. Atlantic Mackerel	*Scomber scombrus*	MAFMC	Mackerel, Squid, and Butterfish	50.75	Planktivore	3.7	60	Pelagic	
79. John Dory	*Zenopsis conchifer*	Unmanaged	NA	#N/A	Planktivore		80		
80. Acadian Redfish	*Sebastes fasciatus*	NEFMC	NE Multispecies	0.01	Planktivore-Piscivore	4	30	Soft sediments, gravel, and rocky habitats	100-300
81. Chain Dogfish	*Scyliorhinus retifer*	Unmanaged	NA	0.05	Small Shark		48		

Table 14. Species Complexes of Georges Bank EPU species.

Species	Species Complex	Ecosystem component	Demersal Trawl	Mid-water Trawl	Sink gillnets	Drift gillnets	Bottom longline	Drift longline	Pot	Seine	Dredge	Demersal recreational	Pelagic recreational	Protected species consumption
1. Yellowfin Tuna	Apex Predator							X					X	
2. Bluefin Tuna	Apex Predator							X					X	
3. Swordfish	Apex Predator					X		X					X	
4. Other Skarks	Apex Predator	X											X	
5. Atlantic Wolffish	Benthivore											X		
6. Channel Whelk	Benthivore								X		X			
7. Blue Crab	Benthivore								X					
8. Jonah Crab	Benthivore								X					
9. Cancer Crabs	Benthivore								X					
10. Black Sea Bass	Benthivore								X			X		
11. Red Crab	Benthivore	X							X					
12. Witch Flounder	Benthivore		X											
13. American Plaice, > 20	Benthivore		X											
14. American Lobster	Benthivore		X						X					
15. Rosette Skate	Benthivore		X											
16. Yellowtail Flounder	Benthivore		X							X				
17. Golden Tilefish	Benthivore		X		X		X					X		

Species	Species Complex	Ecosystem component	Demersal Trawl	Mid-water Trawl	Sink gillnets	Drift gillnets	Bottom longline	Drift longline	Pot	Seine	Dredge	Demersal recreational	Pelagic recreational	Protected species consumption
18. Haddock	Benthivore		X		X					X		X		
19. Smooth Dogfish	Benthivore		X									X		
20. Lady Crab	Benthivore	X							X					
21. Northern Searobin	Benthivore	X										X		
22. Striped Searobin	Benthivore	X										X		
23. Winter Flounder	Benthivore		X							X		X		
24. Scup	Benthivore		X						X			X		
25. Tautog	Benthivore	X										X		
26. Cunner	Benthivore	X										X		
27. Ocean Pout	Benthivore											X		
28. Spider Crab	Benthivore	X							X					
29. Octopus	Benthivore	X												
30. Conchs	Benthivore								X		X			
31. Sea Urchin	Benthivore	X												
32. Ocean Quahog	Benthos										X			
33. Mussels	Benthos										X			
34. Sea Scallop (Live)	Benthos										X			
35. Surf clam (Live)	Benthos										X			
36. Sea Cucumber	Benthos	X												
37. American plaice, < 20	Macroplanktivore	X												
38. Lumpfish	Macroplanktivore	X												
39. Shortfin squid	Macroplanktivore													X

Species	Species Complex	Ecosystem component	Demersal Trawl	Mid-water Trawl	Sink gillnets	Drift gillnets	Bottom longline	Drift longline	Pot	Seine	Dredge	Demersal recreational	Pelagic recreational	Protected species consumption
40. Longfin Squid	Macroplanktivore		X											X
41. Longhorn Sculpin	Macroplanktivore	X										X		
42. Red hake < 40	Macroplanktivore		X											
43. Spiny Dogfish < 60 cm	Piscivore		X		X		X					X		
44. White hake, 20 – 40	Macroplanktivore		X											
45. White hake, < 20	Macroplanktivore		X											
46. Cusk	Macrozoo-piscivore	X					X					X		
47. Blackbelly Rosefish	Macrozoo-piscivore	X										X		
48. Little Skate	Macrozoo-piscivore		X		X					X		X		
49. Smooth Skate	Macrozoo-piscivore	X												
50. Pollock	Macrozoo-piscivore		X		X							X		
51. Clearnose Skate	Macrozoo-piscivore		X											
52. Windowpane	Macrozoo-piscivore		X											
53. Red Hake, < 40	Macrozoo-piscivore		X							X		X		
54. Offshore hake, < 40	Macrozoo-piscivore													
55. Silver hake, < 40 56.	Macrozoo-piscivore													
57. Blueback Herring	Mesoplanktivore			X						X				X

Species	Species Complex	Ecosystem component	Demersal Trawl	Mid-water Trawl	Sink gillnets	Drift gillnets	Bottom longline	Drift longline	Pot	Seine	Dredge	Demersal recreational	Pelagic recreational	Protected species consumption
58. Alewife	Mesoplanktivore			X						X				X
59. American Shad	Mesoplanktivore			X										
60. Atlantic Menhaden	Mesoplanktivore			X						X				X
61. Atlantic Herring	Mesoplanktivore			X						X				X
62. Thorny Skate	Piscivore	X												
63. Weakfish	Piscivore													
64. Barndoor Skate	Piscivore	X												
65. Atlantic Cod	Piscivore		X		X		X			X		X		
66. Sea Raven	Piscivore	X										X		
67. Fourspot Flounder	Piscivore	X												
68. Atlantic Halibut	Piscivore		X				X					X		
69. Winter Skate	Piscivore		X		X							X		
70. Goosefish	Piscivore		X		X					X	X	X		
71. Offshore Hake, > 40	Piscivore		X											
72. Silver Hake, > 40	Piscivore		X				X			X		X		
73. Striped Bass	Piscivore											X		
74. Summer Flounder	Piscivore		X		X							X		
75. Bluefish	Piscivore		X										X	
76. Spiny Dogfish > 60 cm	Piscivore		X		X		X					X		
77. White Hake, > 40	Piscivore		X		X		X					X		

Species	Species Complex	Ecosystem component	Demersal Trawl	Mid-water Trawl	Sink gillnets	Drift gillnets	Bottom longline	Drift longline	Pot	Seine	Dredge	Demersal recreational	Pelagic recreational	Protected species consumption
78. Butterfish	Planktivore			X										
79. Atlantic Mackerel	Planktivore			X						X			X	
80. John Dory	Planktivore	X												
81. Acadian Redfish	Planktivore-Piscivore		X		X							X		
82. Chain Dogfish	Small Shark													

10.9 List of Georges Bank species by management authority and Species Complex.

Table 15. Summary of Georges Bank EPU biomass estimates (average of catchability-adjusted swept area biomass for the 2015 spring and fall bottom trawl surveys) for species often caught in the **bottom trawl fishery.**

Total biomass, '000 mt	Feeding guild					
Management/species	**Benthivore**	**Macroplanktivore**	**Macrozoo-piscivore**	**Piscivore**	**Planktivore-Piscivore**	**Total**
ASMFC	**23.3**					**23.3**
American Lobster	16.7					16.7
Smooth Dogfish	6.6					6.6
MAFMC		**28.8**		**5.6**		
Bluefish				5.6		5.6
Golden Tilefish						
Longfin Squid		28.8				28.8
MAFMC/ASMFC	**19.0**			**4.7**		**23.7**
Scup	19.0					19.0
Summer Flounder				4.7		4.7
MAFMC/NEFMC				**384.8**		**384.8**
Spiny Dogfish				384.8		384.8
NEFMC	**950.4**			**182.8**	**0.0**	
American Plaice	0.9					0.9
Atlantic Cod				15.6		15.6
Atlantic Halibut				0.6		0.6
Clearnose Skate						
Haddock	938.8					938.8
Little Skate			68.0			68.0
Offshore Hake				0.1		0.1
Pollock			0.3			0.3
Red Hake			10.5			10.5
Rosette Skate	0.1					0.1
Silver Hake				19.5		19.5
White Hake				0.5		0.5
Winter Flounder	9.0					9.0
Winter Skate				146.6		146.6
Witch Flounder	0.1					0.1
Yellowtail Flounder	1.6					1.6
Windowpane			2.6			2.6
Acadian Redfish					0.0	0.0
NEFMC/MAFMC				**1.2**		**1.2**
Goosefish				1.2		1.2
Total		**28.8**		**579.2**	**0.0**	

Table 16. Summary of Georges Bank EPU biomass estimates (average of catchability-adjusted swept area biomass for the 2015 spring and fall bottom trawl surveys) for species often caught in the **mid-water trawl fishery.**

Total biomass, '000 mt	Feeding guild		
Management/species	Mesoplanktivore	Planktivore	Total
ASMFC	**2.3**		**2.3**
Alewife	1.0		1.0
American Shad	0.8		0.8
Blueback Herring	0.5		0.5
MAFMC		**62.2**	
Atlantic Mackerel		50.8	50.8
Atlantic Menhaden			
Butterfish		11.5	11.5
NEFMC/ASMFC	**601.7**		**601.7**
Atlantic Herring	601.7		601.7
Total		**62.2**	

Table 17. Summary of Georges Bank EPU biomass estimates (average of catchability-adjusted swept area biomass for the 2015 spring and fall bottom trawl surveys) for species often caught in the **sink gillnet fishery.**

Total biomass, '000 mt	Feeding guild				
Management/species	Benthivore	Macrozoo-piscivore	Piscivore	Planktivore-Piscivore	Total
MAFMC					
Golden Tilefish					
MAFMC/ASMFC			**4.7**		**4.7**
Summer Flounder			4.7		4.7
MAFMC/NEFMC			**384.8**		**384.8**
Spiny Dogfish			384.8		384.8
NEFMC	**938.8**	**68.3**	**162.6**	**0.0**	**1,169.7**
Atlantic Cod			15.6		15.6
Haddock	938.8				938.8
Little Skate		68.0			68.0
Pollock		0.3			0.3
White Hake			0.5		0.5
Winter Skate			146.6		146.6
Acadian Redfish				0.0	0.0
NEFMC/MAFMC			**1.2**		**1.2**
Goosefish			1.2		1.2
Total		**68.3**	**553.4**	**0.0**	

Table 18. Summary of Georges Bank EPU biomass estimates (average of catchability-adjusted swept area biomass for the 2015 spring and fall bottom trawl surveys) for species often caught in the **bottom longline fishery.**

Total biomass, '000 mt	Feeding guild			
Management/species	Benthivore	Macrozoo-piscivore	Piscivore	Total
MAFMC				
Golden Tilefish				
MAFMC/ASMFC			**4.7**	**4.7**
Summer Flounder			4.7	4.7
MAFMC/NEFMC			**384.8**	**384.8**
Spiny Dogfish			384.8	384.8
NEFMC			**36.2**	**36.2**
Atlantic Cod			15.6	15.6
Atlantic Halibut			0.6	0.6
Silver Hake			19.5	19.5
White Hake			0.5	0.5
Unmanaged				
Cusk				
Total			**425.7**	

Table 19. Summary of Georges Bank EPU biomass estimates (average of catchability-adjusted swept area biomass for the 2015 spring and fall bottom trawl surveys) for species often caught in the **pelagic longline fishery.**

Total biomass, '000 mt	Feeding guild	
Management/species	Apex Predator	Total
NMFS-SFD		
Bluefin Tuna		
Swordfish		
Yellowfin Tuna		
Total		

Table 20. Summary of Georges Bank EPU biomass estimates (average of catchability-adjusted swept area biomass for the 2015 spring and fall bottom trawl surveys) for species often caught in the **pot fishery.**

Total biomass, '000 mt Management/species	Feeding guild Benthivore	 Total
ASMFC	**17.0**	**17.0**
American Lobster	16.7	16.7
Jonah Crab	0.3	0.3
MAFMC/ASMFC	**19.2**	**19.2**
Black Sea Bass	0.2	0.2
Scup	19.0	19.0
NEFMC		
Red Crab		
Unmanaged		
Blue Crab		
Cancer Crabs		
Channel Whelk		
Conchs		
Lady Crab	1.7	1.7
Spider Crab		
Total		

Table 21. Summary of Georges Bank EPU biomass estimates (average of catchability-adjusted swept area biomass for the 2015 spring and fall bottom trawl surveys) for species often caught in the **seine fishery.**

Total biomass, '000 mt Management/species	Feeding guild Benthivore	 Macrozoo-piscivore	 Mesoplanktivore	 Piscivore	 Planktivore	 Total
ASMFC			**1.5**			**1.5**
Alewife			1.0			1.0
Blueback Herring			0.5			0.5
MAFMC					**50.8**	
Atlantic Mackerel					50.8	50.8
Atlantic Menhaden						
NEFMC	**949.3**	**78.5**		**35.1**		**1,063.0**
Atlantic Cod				15.6		15.6
Haddock	938.8					938.8
Little Skate		68.0				68.0
Red Hake		10.5				10.5
Silver Hake				19.5		19.5
Winter Flounder	9.0					9.0
Yellowtail Flounder	1.6					1.6
NEFMC/ASMFC			**601.7**			**601.7**
Atlantic Herring			601.7			601.7
NEFMC/MAFMC				**1.2**		**1.2**
Goosefish				1.2		1.2
Total	949.3	78.5		36.3	50.8	

Table 22. Summary of Georges Bank EPU biomass estimates (average of catchability-adjusted swept area biomass for the 2015 spring and fall bottom trawl surveys) for species often caught in the **dredge fishery.**

Total biomass, '000 mt	Feeding guild			
Management/species	Benthivore	Benthos	Piscivore	Total
MAFMC				
Ocean Quahog				
Surf clam (Live)		0.0		0.0
NEFMC		**37.4**		**37.4**
Sea Scallop (Live)		37.4		37.4
NEFMC/MAFMC			**1.2**	**1.2**
Goosefish			1.2	1.2
Unmanaged				
Channel Whelk				
Conchs				
Mussels				
Total			**1.2**	

Table 23. Summary of Georges Bank EPU biomass estimates (average of catchability-adjusted swept area biomass for the 2015 spring and fall bottom trawl surveys) for species often caught in the **demersal recreational fishery.**

Total biomass, '000 mt	Feeding guild					
Management/species	**Benthivore**	**Macroplanktivore**	**Macrozoo-piscivore**	**Piscivore**	**Planktivore-Piscivore**	**Total**
ASMFC				**0.3**		
Smooth Dogfish	6.6					6.6
Striped Bass				0.3		0.3
Tautog						
MAFMC						
Golden Tilefish						
MAFMC/ASMFC	**19.2**			**4.7**		**23.9**
Black Sea Bass	0.2					0.2
Scup	19.0					19.0
Summer Flounder				4.7		4.7
MAFMC/NEFMC				**384.8**		**384.8**
Spiny Dogfish				384.8		384.8
NEFMC	**949.0**	**5.2**	**78.8**	**182.7**	**0.0**	**1,215.7**
Atlantic Cod				15.6		15.6
Atlantic Halibut				0.6		0.6
Atlantic Wolffish	0.2					0.2
Haddock	938.8					938.8
Little Skate			68.0			68.0
Ocean Pout	1.1					1.1
Pollock			0.3			0.3
Red Hake			10.5			10.5
Silver Hake				19.5		19.5
White Hake				0.5		0.5
Winter Flounder	9.0					9.0
Winter Skate				146.6		146.6
Longhorn Sculpin		5.2				5.2
Acadian Redfish					0.0	0.0
NEFMC/MAFMC				**1.2**		**1.2**
Goosefish				1.2		1.2
Unmanaged				**5.3**		
Cunner	1.2					1.2
Cusk						
Northern Searobin	0.8					0.8
Sea Raven				5.3		5.3
Striped Searobin						
Blackbelly Rosefish			3.2			3.2
Total		**5.2**		**579.2**	**0.0**	

Table 24. Summary of Georges Bank EPU biomass estimates (average of catchability-adjusted swept area biomass for the 2015 spring and fall bottom trawl surveys) for species often caught in the **pelagic recreational fishery.**

Total biomass, '000 mt	Feeding guild			
Management/species	Apex Predator	Piscivore	Planktivore	Total
ASMFC				
Other Skarks				
MAFMC		**5.6**	**50.8**	**56.4**
Atlantic Mackerel			50.8	50.8
Bluefish		5.6		5.6
NMFS-SFD				
Bluefin Tuna				
Swordfish				
Yellowfin Tuna				
Total		**5.6**	**50.8**	

Table 25. Summary of Georges Bank EPU biomass estimates (average of catchability-adjusted swept area biomass for the 2015 spring and fall bottom trawl surveys) for species often consumed by **protected species.**

Total biomass, '000 mt	Feeding guild		
Management/species	Macroplanktivore	Mesoplanktivore	Total
ASMFC		**1.5**	**1.5**
Alewife		1.0	1.0
Blueback Herring		0.5	0.5
MAFMC	**30.3**		
Atlantic Menhaden			
Longfin Squid	28.8		28.8
Shortfin squid	1.5		1.5
NEFMC/ASMFC		**601.7**	**601.7**
Atlantic Herring		601.7	601.7
Total	**30.3**		

11.0 Glossary

Apex Predators: A group of species defining a trophic guild that contains typically large, fast moving predators that feed at the top of the food web

Assessment model: A statistical tool used to assess the status of a trophic guild, multispecies complex or stock. Assessments can range from an empirical indicator to more complex techniques such as an age-structured population model.

Benthivores: A group of species defining a trophic guild that consume benthic invertebrates, principally species in the benthos trophic guild

Benthos: A group of species that are suspension and deposit feeders, principally crustaceans and mollusks

Ecological production unit: A defined area containing all or the majority of an ecosystem where place based management would be implemented. Species and fishing vessels move between ecological production units, but regulations on extraction are defined and implemented within a specific ecological production unit to ensure that the total removals from an ecosystem are directly linked to the productivity of that ecosystem.

Ecosystem exploitation rate: The rate of removals by fishing for the total exploitable biomass within an ecosystem production unit.

Empirical indicator: A quantity that can be consistently measured through type and provides information on the ecosystem. The current survey biomass of a species compared to its historic survey biomass is one of many potential indicators of the species status.

Species Complex: A group of species that are caught together, share common life history characteristics, and play similar roles in the ecosystem with respect to energy transfer (e.g. eat similar food items).

Macroplanktivores: A group of species defining a trophic guild that consume macrozooplankton, principally amphipods but including decapod shrimp

Macrozoo-Piscivores: A group of species defining a trophic guild that consume macrozooplankton, shrimp and euphausiids among others, and fish

Management objective: A clearly defined goal for the status of the ecosystem or parts of it and/or the status of the social/economic components for people relying on the ecosystem

Management procedure: An action that alters the intensity of fishing, the location of fishing or the seasonal timing of fishing for trophic guilds, multispecies complexes or stocks. Management procedures can include, but are not limited to changes in catch quotas, changes in effort, changes in gear, changes in open and closed fishing areas and changes in seasonal open and closed time periods.

Management strategy evaluation: A stakeholder lead process in which a range of management procedures are tested within a virtual representation of an ecosystem. A simulation model, termed an operating model, contains all the essential components of an ecosystem and represents reality. The Fishing and scientific surveys take place within the simulation model, and assessment models are fit to these outputs. The biomass estimates from the assessment models trigger the stakeholder developed management procedures that feed back into the simulation model through changes in fishing. After numerous iterations, management procedures can be examined to determine how well they performed relative to the stakeholder developed management objectives.

Mesoplanktivores: A group of species defining a trophic guild that consume mesozooplankton, principally copepods

MSY (Maximum Sustainable Yield): A calculated value of the maximum yield that can taken sustainably from a resource, traditionally applied to single stocks but also may apply to a stock complex of trophically-related species within an ecosystem.

Operating model: A simulation model used within a management strategy evaluation framework. The operating model represents reality and contains all the essential components of an ecosystem needed to examine specific management procedures. It iteratively incorporates fishing levels set as directed by a management procedure with ecological dynamics to output annual harvested biomass and scientific survey biomass. Operating models may also simulate social and economic components of a fished ecosystem.

Piscivores: A group of species defining a trophic guild that consume mainly fish species

Place-Based Management: A management approach that applies to all species and stock in a specified area associated with an ecosystem of trophically-linked species.

Primary Productivity: A measure of the total amount of energy in an ecosystem at the base of the food web. The primary productivity defines the amount of energy available to higher trophic levels and therefore can be used to set the limit on total removals from the ecosystem.

Stock-Based Management: A management approach that applies to single stocks in a fishery.

Stochastic model simulations: Deterministic ecosystem model runs in which random variability is added to components of the model.

Trophic guilds: A group of species that utilize similar resources such as feeding on similar items or have similar dietary requirements and therefore can help define a Species Complex

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