NEW ENGLAND FISHERY MANAGEMENT COUNCIL

Draft Example Fishery Ecosystem Plan for Georges Bank

prepared by the

Ecosystem Based Fishery Management

Plan Development Team

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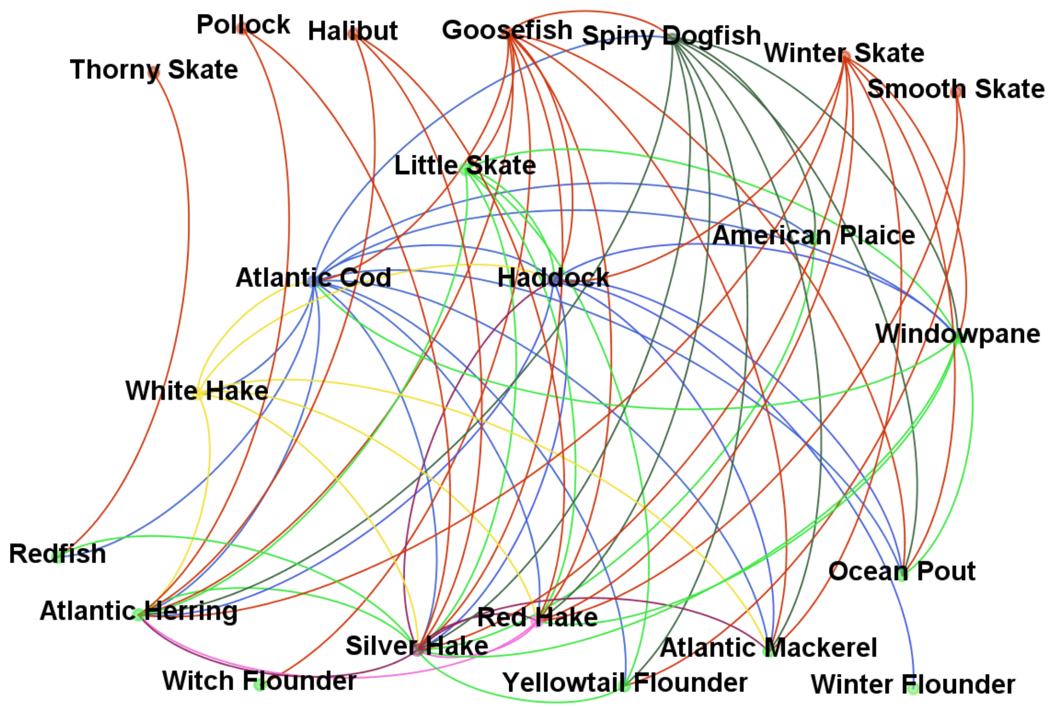

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1.0 Executive Summary and Overview

This document describes a management approach, or operational framework, to conduct an evaluation of potential ecosystem management strategies using one or more operating models.

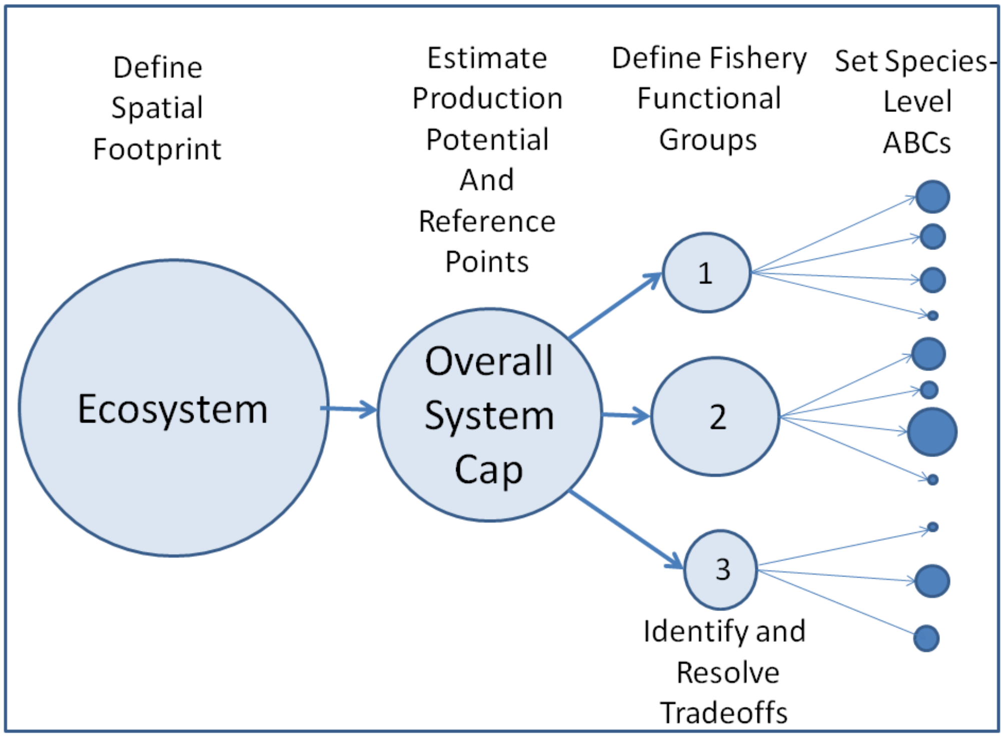
For purposes of further analysis and discussion, this document lays out a description of an analytical framework for a Fishery Ecosystem Plan for the Georges Bank Ecosystem Production Unit as a proof of concept. It provides core elements of a Fishery Ecosystem Plan to set the stage for full development of an FEP. Further guidance from the council with respect to its objectives for EBFM will be required to enter the next phase of FEP development. 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 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 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 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 5.1). Catch limits by Species Complex would be allocated, but in aggregate should not exceed the EPU catch cap that would define overfishing (Section 5.2). Biomass ‘floors’ would be established to protect species from becoming unacceptably overfished or depleted (Section 5.2). 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 and 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 17). 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 6.0). 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 unfinished sections (Section 8.0, 9.0, and 10.0) toward the end of the document that focus on the process for using the operational models 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 11.0includes a summary and description of the Georges Bank EPU. In total, this document describes an operating framework, but it is not the Fishery Ecosystem Plan itself. The latter would include additional features like strategic goals and objectives, as well as some broad management approaches that the PDT has begun developing. Much of this latter work raises questions when finished will help with the dialogue with and between fishermen, stakeholders, and managers.

1.1 Problem statement

Currently, the Councils manage mortality on individual stocks, with minimal regard to how they are caught together or have a primary predator/prey relationship. Stocks are managed to achieve an estimate of MSY for a stock, often with little regard of whether this is achievable for all stocks in a plan (much less between plans), what the expected benefits of achieving MSY are, or how the stock interacts with other related components of the ecosystem. The sum of, and even on an individual basis, these MSY estimates may be considerably higher than that produced by the ecosystem and are thus unattainable. FMPs do not often address stakeholders that indirectly rely on the managed resources, fishery valued on the harvest side, but rarely considers benefits to other species and fisheries and businesses that rely on them.

To fish using a specific gear in an area, fishermen often need to accrue a suite of permits or discard species for which they have no permits to land them. Many of these permits require qualification through a limited access program and are difficult or costly to obtain. Permitting, enforcement, and discarding are thus all economically expensive and inefficient. Also, low catch limits for depleted stocks can create a choke situation where either healthier stocks cannot be targeted without unacceptably high mortality on the choke species, yield is foregone for the healthy stocks, or the current management system imposes large economic costs on fishermen to lease or buy allocations and continue fishing. Talk about FMPs managing one activity. Regulations are not streamlined and difficult to understand, much less comply.

Furthermore, with rare exception, the stocks are managed individually by often separate FMPs with catch limits without regard to the needs of anything but commercial and recreational fishing interests. With the exception of recent efforts to improve the Atlantic herring harvest control rule, providing adequate forage for fish, seabirds, and whales is generally not considered, except in the belief that independently derived MSY estimates for individual stocks will satisfy this ecological demand.

There are gaps in data and monitoring across the various FMPs that apply to Georges Bank species. Although the recently develop Ecosystem Monitoring Reports partially addresses the problem, there is not a routine ecosystem monitoring component that tracks the overall health of the ecosystem and the role that management of that species plays in it.

1.2 Vison statement

The NEFMC's vision is ecosystem-based fishery management that harmonizes what is known, unknown, and unknowable about fishery resources and ecosystems with realities of fishing operations, and the law. Catches on Georges Bank would be managed by fishery and with consideration of a broader range of ecosystem objectives and considerations, "including trophic interactions between fished and un-fished species , and impacts on non-fishery elements including habitats and regional communities

As a result, the NEFMC expects:

- take account of interactions between fishery resource species,
- healthy ecosystems, including exploited and non- exploited species,
- greater stability in fishery management and fishing opportunities,
- more flexibility in fishing operations,
- less complex fishery management,
- reduced discarding

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1.3 Description of Key Features

Fishing within the Georges Bank EPU would be managed using a more dynamic and flexible approach. MSY for the EPU based on the sum of MSY for stock complexes and would limit overall EPU catch, subject to limits of primary productivity. Stock complexes would be defined as stocks that have similar trophic and life history characteristics, each having an MSY estimate that is more harmonious with the role of the species in the ecosystem. An example of a stock complex is flatfish that feed on the benthos (e.g. flounders and skates). Another example is piscivorous (fish eating) benthic roundfish (e.g. cod, pollock, monkfish, and silver hake).

Objectives would be identified that serve multiple needs, including production of economic value, sustenance of fishing communities, and support of fish, birds, sea turtles, and marine mammals at higher trophic levels. Some stock complexes could be limited at higher or lower mortality levels depending on the productivity of species in the complex and the needs of the ecosystem.

Reference points and harvest control rules would be developed for stock complexes, including accountability measures that apply at this level. The harvest control rule would define an Annual Catch Limit for the stock complex.

Protection against excessive depletion would apply as it is now as an overfished level for stocks, but the threshold would vary from existing values in consideration of the stock's vulnerability to fishing, resilience (i.e. speed of recovery), and the importance of its role in the ecosystem. If a stock is overfished, a rebuilding plan for the stock would be developed and include a carve-out for a sub-ACL applying to that stock alone and technical measures to limits its catch within the stock complex.

Catch limits would be allocated to functional groups, which are stock complexes caught together in a fishery (defined by gear and possibly area). These functional group catch limits would be equivalent to a sub-ACL with accountability measures that apply if and when the stock complex ACL is exceeded (and overfishing thus had occurred).

Vessels would be permitted on the basis of a fishery, instead of the species that it catches. For example, a vessel could be permitted in the large-mesh trawl fishery and would be allocated catches of functional groups that that fishery normally catches. With the single permit, it would be able to target and retain catches of large-mesh multispecies as well as monkfish, skates, and summer flounder. A vessel with a small-mesh trawl permit, for example, could target and retain catches of whiting, red hake, squid, butterfish, and herring.

Greater use of data sources and ecosystem monitoring would enable better management of the system as a whole and recognize changes in its characteristics due to environmental trends.

1.4 COMPONENTS

Scope – Draft Discussion Document 6

- Area description – Draft Discussion Document 2

- Fisheries
  - E.G. Large-mesh trawl, small-mesh trawl, stand-up gillnet, tie-down gillnet, longline, hook and line, lobster trap, red crab trap, scallop dredge, clam dredge, other.

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• Managed Stocks – all species managed by the NEFMC (MAFMC, ASMFC, NMFS?)

Ecosystem MSY
• MSY for the EPU is determined via the sum of the individual stock complexes. Total EPU catch cannot exceed this amount.

Biological Reference Points and Harvest Control Rules

• Stock complexes
o Maximum catch limits determined for groups of interrelated species (defined by similar diets and life histories)
o MSY for stock complexes is determined by assessment
o Special consideration for forage species and juvenile fish – Draft Discussion Document 10

• Assessment
o Multispecies assessment with interactions every three (?) years
o Single species benchmark assessments for overfished stocks

• Overfishing
o Level determined as the average mortality that would produce MSY for the stock complex, considering the appropriate catch composition to meet plan objectives

• Overfished stocks and Rebuilding – Draft Discussion Document 4
o Level for a stock determined from an evaluation of its
☐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).
o Uses appropriate survey biomass indices and possibly standard commercial catch per unit effort data (lbs. per area swept) to make annual status determinations

Fishing Access and Permitting – Draft Discussion Document 8
• Instead of using a history of landing a specific species, limited access determined by a vessel having a permit to fish for a species that occurs on Georges Bank and has a history of fishing on Georges Bank with a specific gear type (trawl, gillnet, longline, hook and line, trap, clam dredge, scallop dredge, etc.).
• Inshore/offshore fisheries? Flatfish vs. roundfish trawls?
• Permits allow a vessel to use a specific gear type in a specific area (in this case the Georges Bank EPU)
• Vessels could have permits for one or more fisheries, but could not use a trawl permit to fish in a gillnet fishery, for example, but could possibly obtain such a permit from another vessel holding one (i.e. permit splitting is allowed).
• Community permit banking
• Catch sharing via sectors would be allowed, reducing the costs of exceeding a vessel's functional group catch allocation.
• Recreational fishing permits
o Limited access for charter/party boats?

Catch Allotment/Allocation
• Allocations made to permit holders in functional groups of species (i.e. a stock complex caught by gear type)

• A permitted vessel would receive an annual catch allocation of one or more functional groups that are caught by a Georges Bank fishery.
• Recreational catch allocations

Spatial Management Measures for Habitat, Spawning, and Endangered/Threatened Species Protection – Draft Discussion Document 9
• Improvements in productivity through better habitat quality and survival of juvenile fish

Unmanaged and invasive species policies – Draft Discussion Document 12
• Special policies, such as imported bait and closed area effects

Technical measures
• Size- and species-selective gear
• Mandatory retention of marketable species
• Area closures to reduce impacts on spawning, habitat, and/or endangered or threatened species
• Incentives to fish in low-impact, selective fisheries
• Measures to prevent excessive targeting of highest value and/or vulnerable species

Jurisdiction, Cooperation, and Collaboration – Draft Discussion Document 7
• Georges Bank EPU allocations consistent with FMP goals and objectives, not to exceed the EPU MSY limit or the constraints set by plans managed by other authorities
• Procedures for joint or cooperative management of fishing within the EPU.

Advisory Teams
• Individuals with interest in a Georges Bank EPU fishery

Data collection, monitoring, and fishery research – Draft Discussion Document 5
• Gaps in mandatory data collection
• New ecological data
• Electronic monitoring
• Research set-aside (RSA) program – a portion of allowable catch limit is reserved for supporting management-related research

Decision support

Integrated Ecosystem Assessment
• A broad summary of trends in various biological, oceanographic, economic, and social indicators.

Ecosystem Risk Assessment
• Expert opinion indicated the level and immediacy of risk factors that can affect the ecosystem and how well management will achieve its objectives.

Management strategy evaluation (MSE) – Draft Discussion Document 11
• Pre-plan development – objectives evaluation and models
• Simulation and evaluation of management via operating models – Draft Discussion Document 3
• Post plan – standard process for plan amendments

Transition strategy to place-based FEP
• How and when do new changes occur?
• Gradual phase ins?

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• Functional group catch allocations for NEFMC managed species as well as unmanaged stocks initially and later applies to all managed stocks?

2.0 Table of Contents

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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 has 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)*

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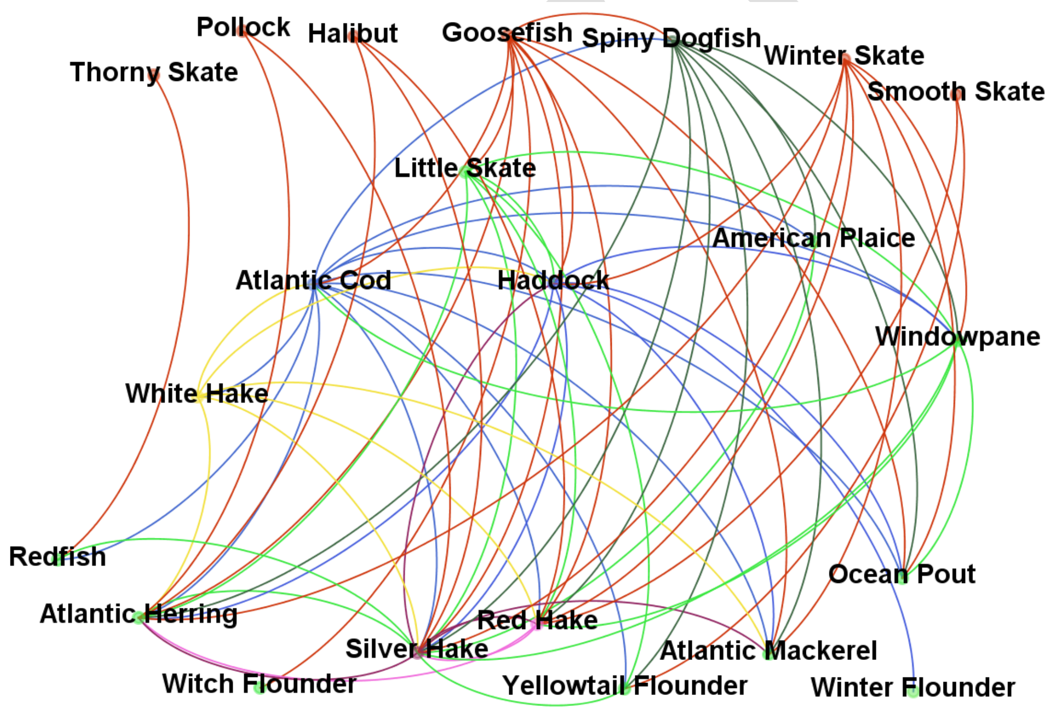
These difficulties have played out in the course of groundfish management in the Northeast over the last several decades, leading to a seemingly intractable problem (Apollonio and Dykstra 2008). Of the stocks managed by NEFMC, fourteen are currently classified as being overfished. Of these, twelve fall 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. 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 Vision Statement

The NEFMC's vision is ecosystem-based fishery management that harmonizes what is known, unknown, and unknowable about fishery resources and ecosystems with realities of fishing operations, and the law. Catches on Georges Bank would be managed by fishery and with consideration of a broader range of ecosystem objectives and considerations, "including trophic interactions between fished and un-fished species , and impacts on non-fishery elements including habitats and regional communities

As a result, the NEFMC expects:

- take account of interactions between fishery resource species,
- healthy ecosystems, including exploited and non- exploited species,

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- greater stability in fishery management and fishing opportunities,
- more flexibility in fishing operations,
- less complex fishery management,
- reduced discarding

5.0 Goals and objectives

5.1 Goals – measurable or desirable outcomes

5.1.1 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)

5.1.2 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

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

5.1.4 Strategic Objectives

1. Manage fisheries and their catches together, rather than as individual stocks

2. Account for total benefits and balance tradeoffs, including economic returns, value to fishing communities, and the needs of a healthy ecosystem.

3. Reduce permitting and compliance costs.

4. Minimize discarding and economic waste (include value of discarded fish, unnecessary steaming and gear costs, enforcement costs, sub-par catch allocations that don't meet overall objectives)

5. Promote and improve the sustainability of fishing communities as well as a diversity of fishery and vessel classes.

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

- Establish overfishing levels based on MSY for the ecosystem, allocated to stock complexes of related species.
- Through Management Strategy Evaluation, develop valuation methods to analyze and balance tradeoffs in setting harvest control rules.
- Develop harvest control rules and associated assessment capabilities that account for trophic relationships.
- Develop flexible harvest control rules that account for changes in the environment and ecosystem.
- Protect stocks from depletion by promoting fishing for resilient and healthy species while discouraging targeting of vulnerable and depleted stocks.
- Allow qualified fishermen to obtain a single permit to fish with a gear type in a specified area.
- Allocate catch limits as a basket of related species.

6.0 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.

7.0 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 several 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.

7.1 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.

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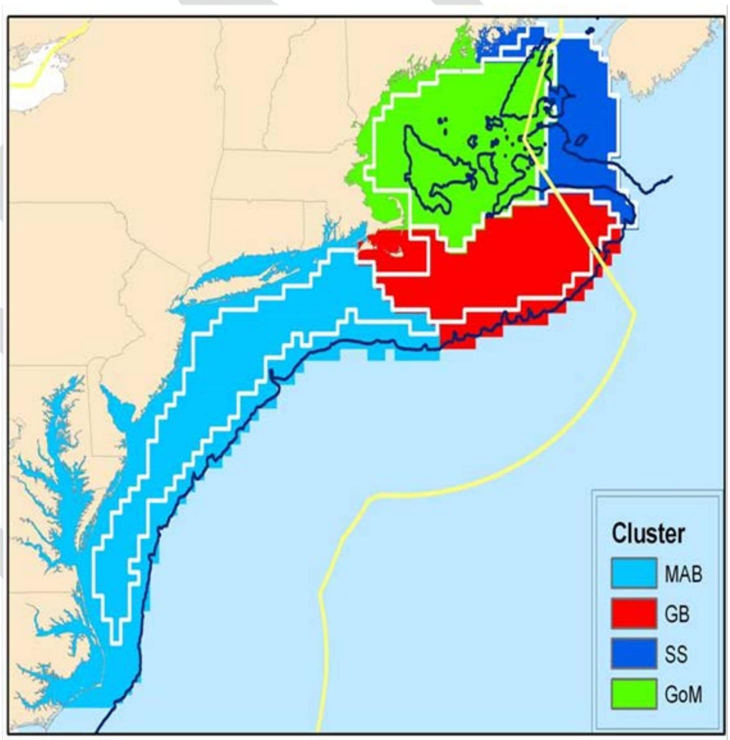
Fogarty et al. (2012; in prep) proposed further consolidation of some ecological subareas to reflect movement patterns of exploited species from both the shelf-break region and the immediate nearshore regions to the adjacent shelf areas. The shelf-break regions are considered special zones associated 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.



7.2 Georges Bank Fisheries

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7.3 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%).

Operational Fishery	Otter Trawl			Longline			Pot			Dredge
	1	5	8	1	2	3	1	2	4	1
Atlantic Cod	grey	light grey		black	black	grey				
Haddock	black	light grey		grey	black	black				
Pollock	light grey				grey					
Silver Hake			light grey							
Monkfish	light grey	light grey								light grey
Winter Flounder	grey	grey								
American Plaice	light grey									
Witch Flounder	light grey									
Summer Flounder		light grey	light grey							
Yellowtail Flounder	light grey	grey								
Skate	light grey	black								
Spiny Dogfish					light grey					

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American Lobster										
Jonah Crab										
Red Crab										
Loligo										
Sea Scallop										

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.

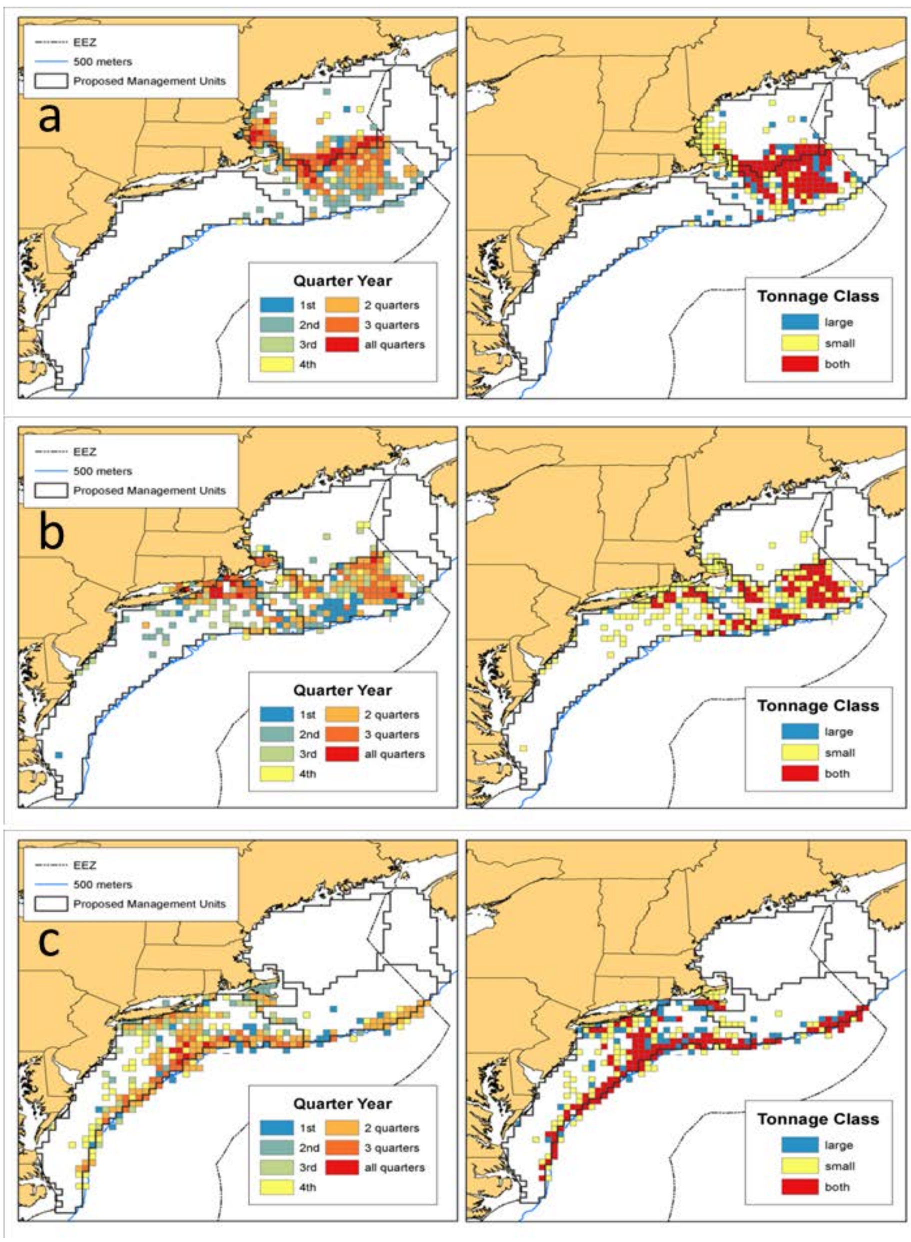


Figure 4. Operational Longline fisheries encompassing Georges Bank: (a) Operational Longline Fishery 1; (b) Operational Longline Fishery 2; (c) Operational Longline Fishery 3. For further information on these designated operational fisheries, see Lucey and Fogarty (2010) and Table 3.1 for dominant species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

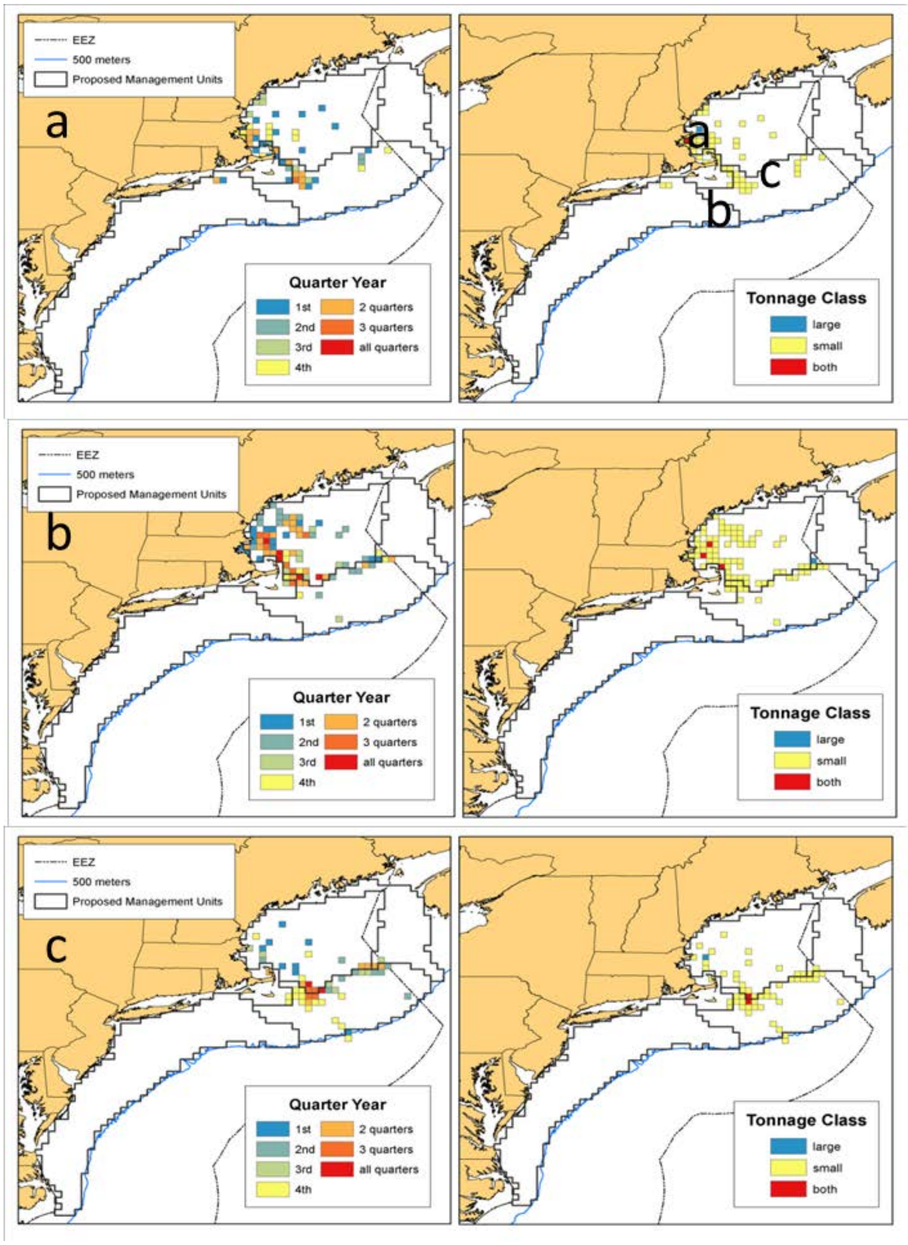


Figure 5. Operational Pot fisheries encompassing Georges Bank: (a) Operational Pot Fishery 1; (b) Operational Pot Fishery 2; (c) Operational Pot Fishery 4. For further information on these designated operational fisheries, see Lucey and Fogarty (2010) and Table 4.1 for dominant species in the catch of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

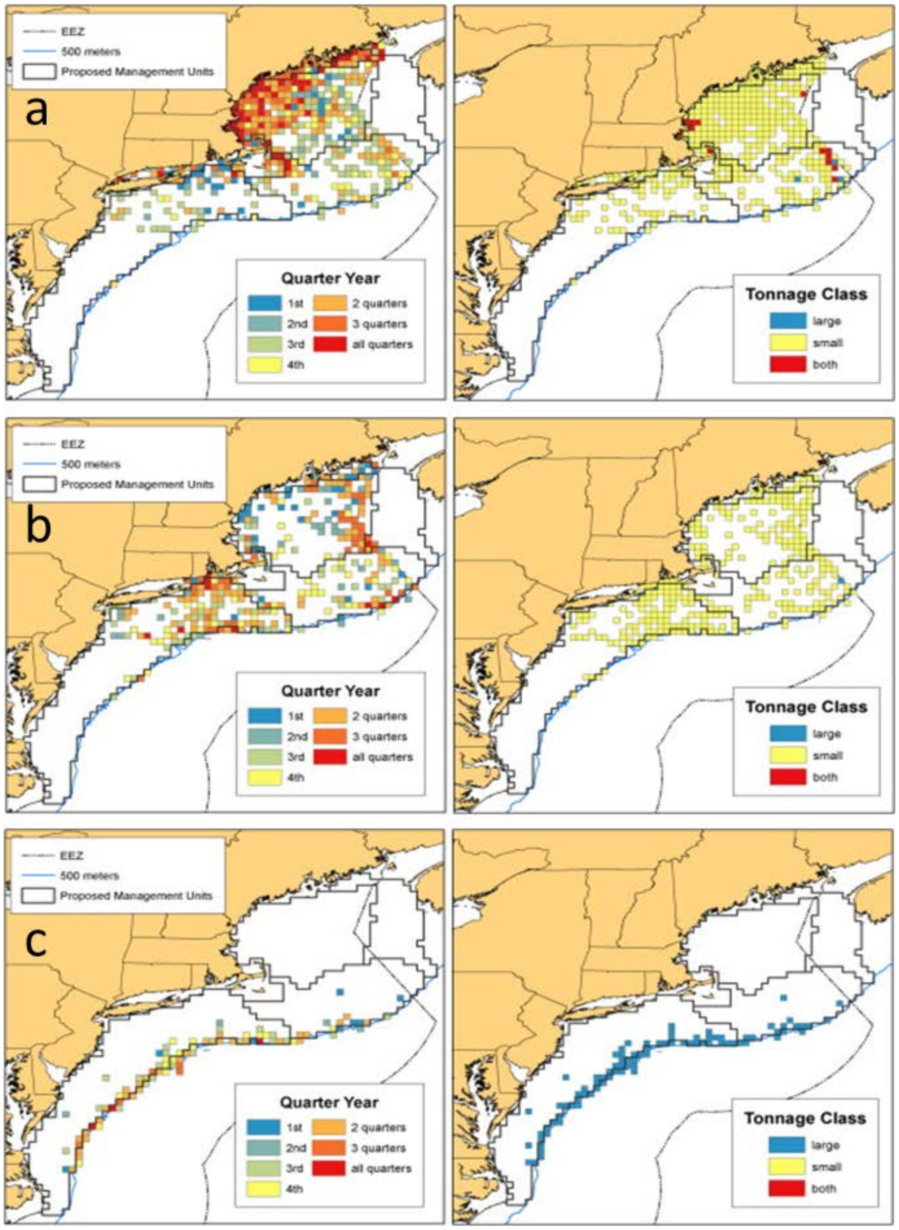
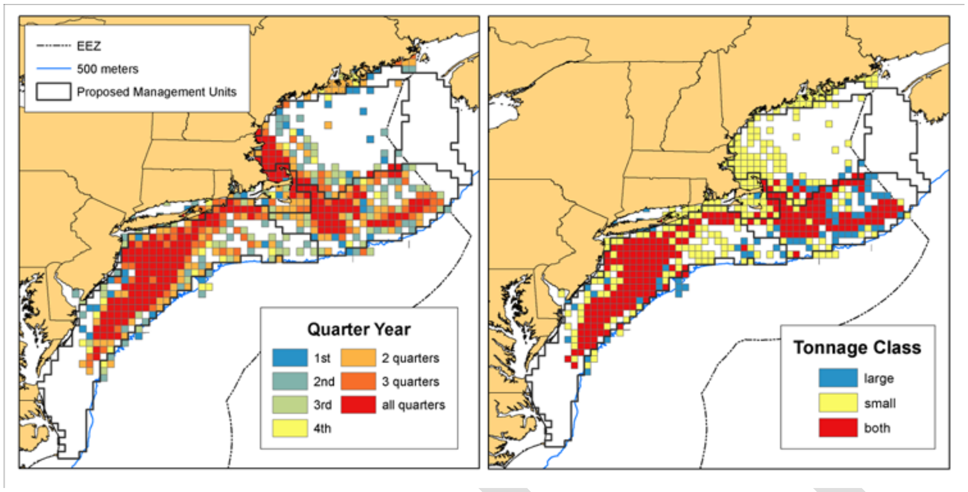


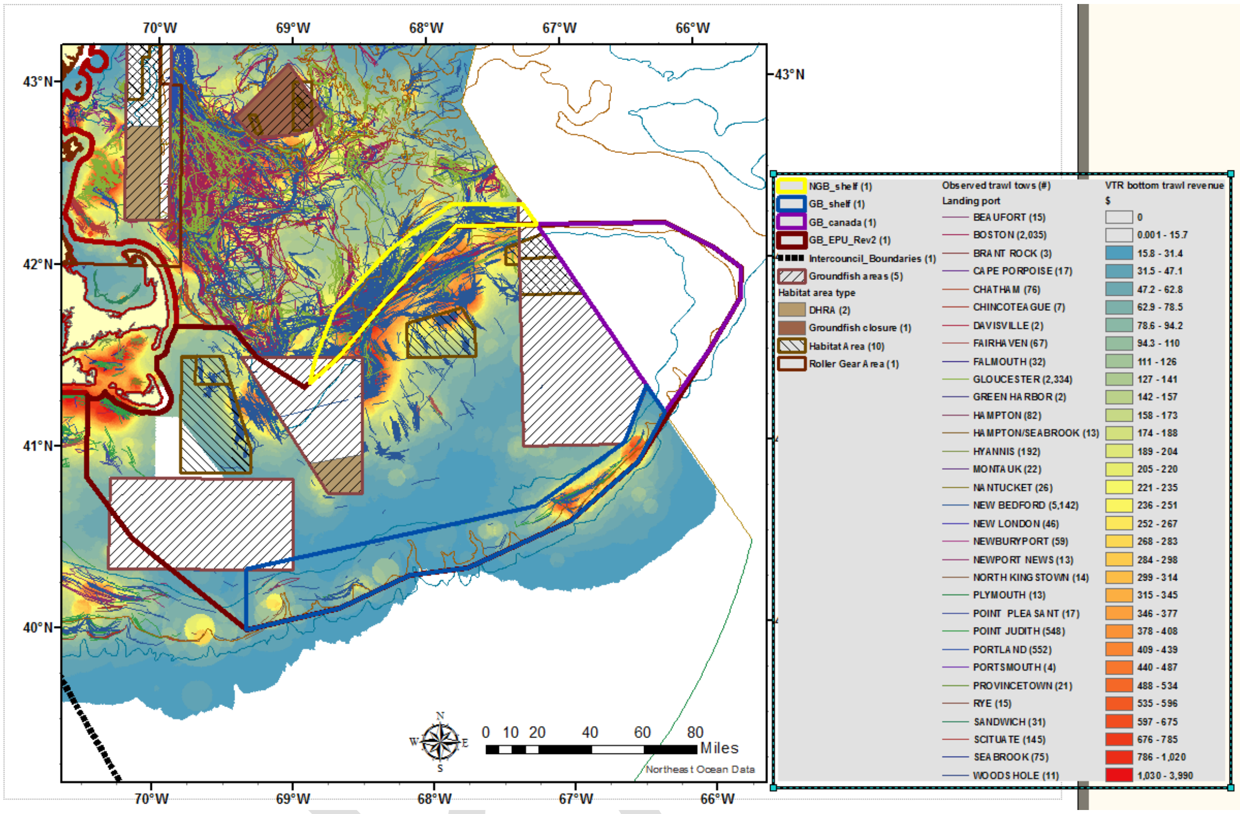
Figure 6. Operational Dredge Fishery 1 encompassing Georges Bank. For further information on these designated operational fisheries, see Lucey and Fogarty (2010) and Table 4.1 for dominant species in the catch of each operational fishery.



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).



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7.4 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. 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.

7.5 Fishery 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 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:

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[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.

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 11.0. 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.

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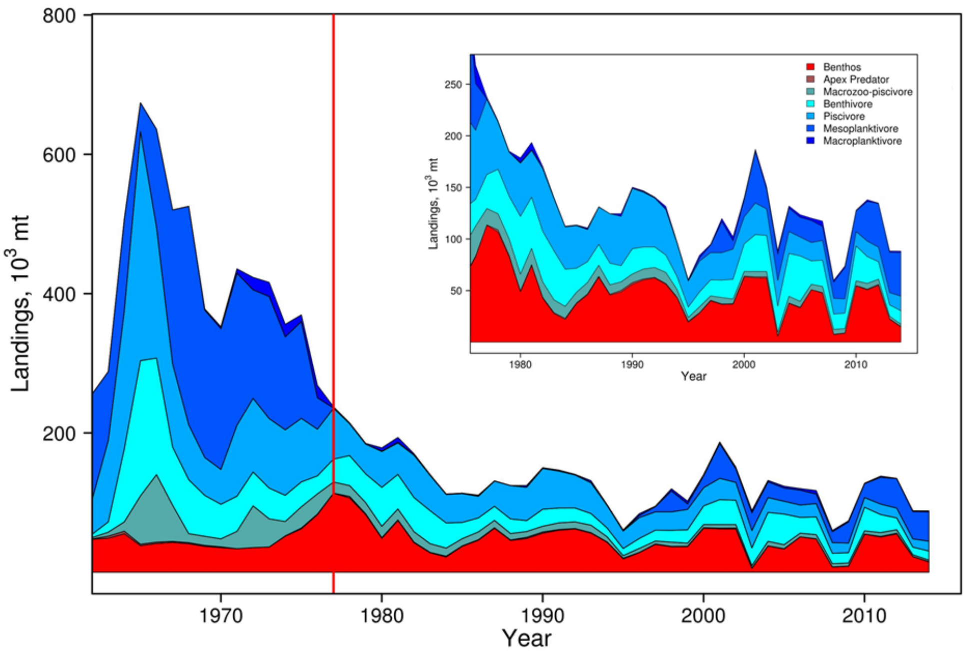
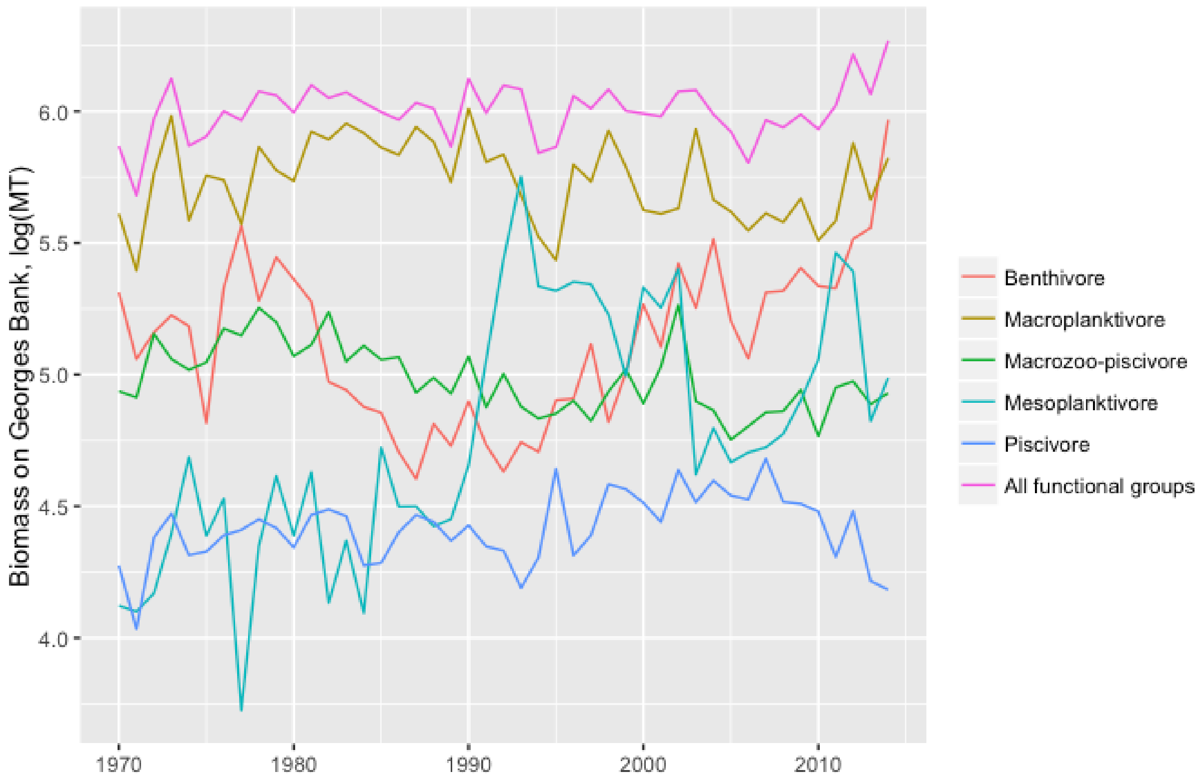
Reported landings on Georges Bank for the period 1964-2015 by the designated Species Complexes are shown in Figure 8. The initial impact of the distant water fleet, and the pattern of sequential depletion of species is clearly evident. By the mid-1980s, reported landings had stabilized (albeit at a slightly 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 Figure 16. 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).



8.0 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

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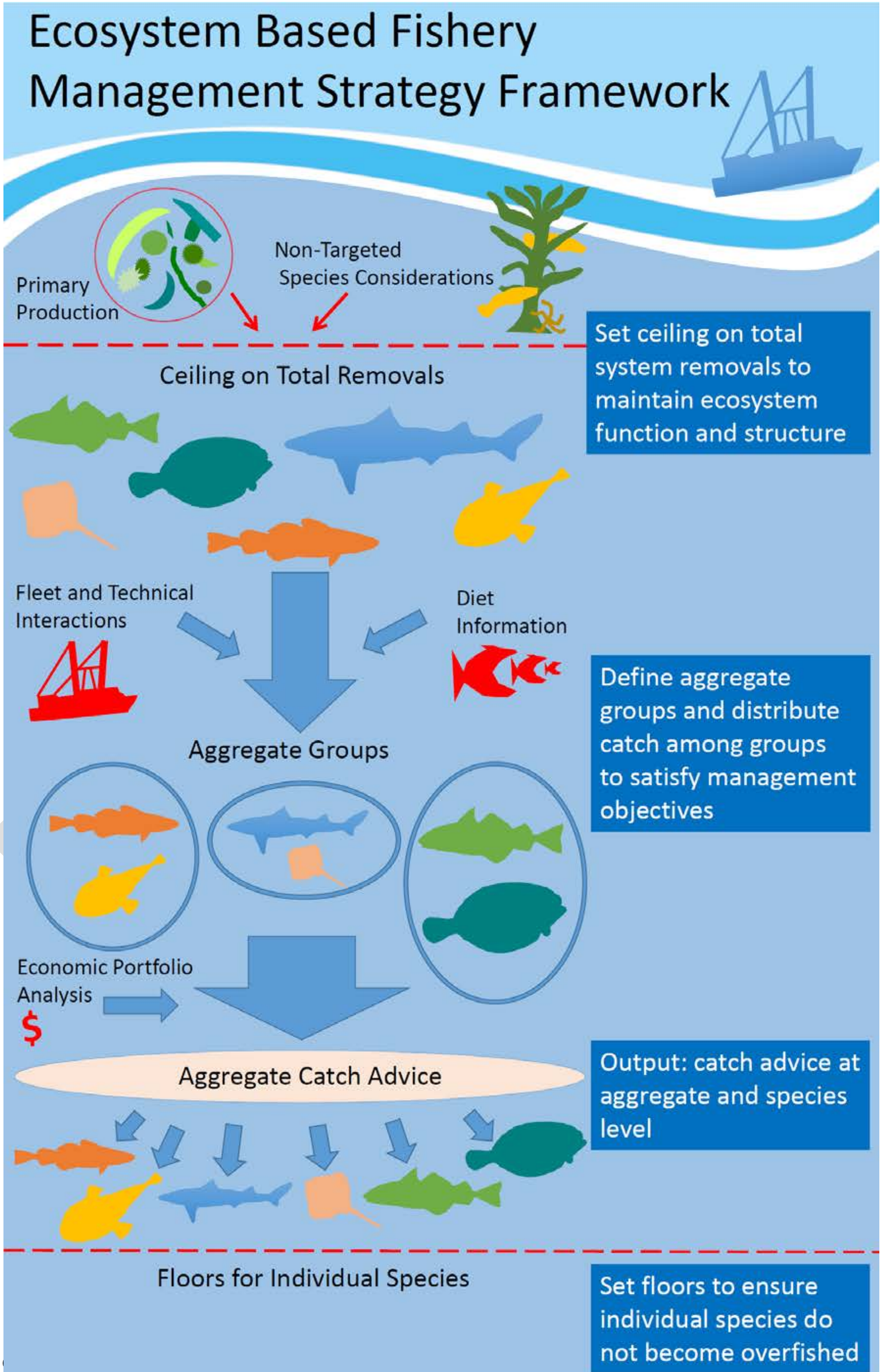


Ecosystem Based Fishery Management Strategy Framework
Primary Production
Non-Targeted Species Considerations
Ceiling on Total Removals
Set ceiling on total system removals to maintain ecosystem function and structure
Fleet and Technical Interactions
Diet Information
Define aggregate groups and distribute catch among groups to satisfy management objectives
Aggregate Groups
Economic Portfolio Analysis
$
Aggregate Catch Advice
Output: catch advice at aggregate and species level
Floors for Individual Species
Set floors to ensure individual species do not become overfished

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.

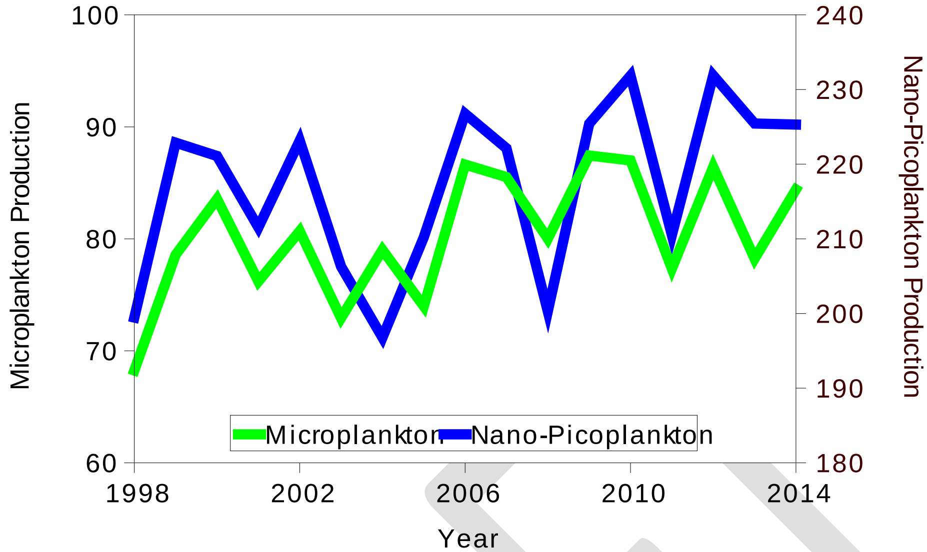
8.1 Ecosystem Reference Points

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 11. The estimated level of primary production on Georges Bank has increased since 1998 (Figure 11) 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 11. 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.

8.2 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 (Wetherill et al. (19???). 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 20th percentile in survey biomass over the time series for teleosts and below the 30th 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 Complexs 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.

8.2.1 Catch Allotment/Allocation

- Allocations made to permit holders in functional groups of species (i.e. a stock complex caught by gear type)
- A permitted vessel would receive an annual catch allocation of one or more functional groups that are caught by a Georges Bank fishery.
- Recreational catch allocations

8.2.2 Jurisdictional authority, cooperation and coordination

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 (PL 111-348). 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.

Subordinate to ecosystem constraints on total removal, the composition of total removals will require management using catch limits specified by Species Complexes. The catch composition specified by Species Complex 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 Species Complex 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 Species Complexs 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 Species Complex 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 Species Complexs 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).

8.2.3 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. 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.

1.1.1. Management of forage species

1.1.1.1. Commercially harvested fisheries

1.1.1.1.1. Food and meal production

1.1.1.1.2. Production for bait

1.1.1.2. Recreationally harvested fisheries for bait

8.3 Overfished species and stocks

1.1.1.3. Status criteria

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 critera 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).

Questions to think about

- How will minimum biomass thresholds be completed for species that are in the EPU for only part of the year?
- What data will be used to monitor each species? How will appropriate indicators be developed and evaluated (is 25th percentile of survey biomass more appropriate than the 50th percentile)?
- If use the NEFSC trawl survey data, how will species be handled that are either not well sampled by the trawl survey or whose range extends outside of the survey footprint (making the assumption of constant availability an issue)? How will changes in catchability and/or availability be handled?
  - Create a list of species that are well-sampled by the survey vs. species that aren't. Which species have low catchability (e.g., bluefish, sharks, cusk)? Which species have ranges extensively outside of the survey area (e.g., estuarine spp., thorny skate, tilefish, mackerel)? This impacts the uncertainty inherent in survey trends for any given stock and carries through any modeling efforts.
- How often will minimum biomass thresholds be reevaluated? Especially important given climate change, which may influence species-specific productivity and/or availability
- Give example minimum biomass thresholds for each of the primary Georges Bank species

    - Are there certain circumstances where a higher minimum biomass threshold would be required (more difficult to rebuild due to life history, forage needs, etc)?
    - Are minimum biomass thresholds only determined for fished species?
- What happens when overfishing, by some definition, occurs?
    - What if catch a greater amount than the system catch? How will catch be reduced, and how will we determine what components (aggregate groups) need to be reduced?
    - Similarly, what if catch a greater amount than the aggregate group catch limit?
    - What happens when a species falls below its species-specific minimum biomass threshold?
        - MSA stock rebuilding requirements would still apply
        - Lower catch limit on the aggregate?
        - Refuges in space or time for that species?
        - Incentives to avoid the species?
    - What if a species is already below its minimum biomass threshold when this approach is first initiated?
- Legality
    - How does proposed approach comply with current law (National Standard guidelines, etc)?
    - Provide discussion of how the proposed revision to National Standard 1 permits these Species Complex analyses and aggregate MSYs; Addresses the depletion versus overfishing question (less emphasis on overfishing and instead emphasizes the minimum biomass threshold concept?)

1.1.1.3.1. Assessment-based
1.1.1.3.2. Survey-based
1.1.1.4. Special priority management
1.1.1.4.1. Special catch limits
1.1.1.4.2. Area or gear restrictions
1.1.1.4.3. Landings prohibition (e.g. thorny skate, smooth skate)
1.1.1.5. Weak link stocks and spatial management considerations
1.1.2. Penalties (e.g. one pound of catch counts for more than a pound of total removal) for catches of depleted, overfished, or key sensitive species, based on minimum stock size thresholds for individual species

Evaluate trends in ecosystem indicators and status (relative to reference points)

9.0 Prototype Ecosystem-Based Management Strategy for Georges Bank

Insert document derived from CIE review material here.

9.1 Biological Reference Points and Harvest Control Rules

9.1.1 Stock complexes

- o Maximum catch limits determined for groups of interrelated species (defined by similar diets and life histories)
- o MSY for stock complexes is determined by assessment
- o Special consideration for forage species and juvenile fish – Draft Discussion Document 10
- o Estimate desired target and trophic balance (spectrum, forage needs); optimized species mix

9.1.2 Assessment

- o Multispecies assessment with interactions every three (?) years
- o Single species benchmark assessments for overfished stocks

9.1.3 Overfishing

- o Level determined as the average mortality that would produce MSY for the stock complex, considering the appropriate catch composition to meet plan objectives

9.1.4 Overfished stocks and Rebuilding – Draft Discussion Document 4

- o Level for a stock determined from an evaluation of its
  - ▪ 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).
- o Uses appropriate survey biomass indices and possibly standard commercial catch per unit effort data (lbs. per area swept) to make annual status determinations

9.1.5 Special Catch Limits for Overfished Stocks – Rebuilding

9.1.6 Weak Link Stocks

9.2 Limited Access and Authorization to Fish

- Instead of using a history of landing a specific species, limited access determined by a vessel having a permit to fish for a species that occurs on Georges Bank and has a history of fishing on Georges Bank with a specific gear type (trawl, gillnet, longline, hook and line, trap, clam dredge, scallop dredge, etc.).

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- Inshore/offshore fisheries? Flatfish vs. roundfish trawls?
- Permits allow a vessel to use a specific gear type in a specific area (in this case the Georges Bank EPU)
- Vessels could have permits for one or more fisheries, but could not use a trawl permit to fish in a gillnet fishery, for example, but could possibly obtain such a permit from another vessel holding one (i.e. permit splitting is allowed).
- Community permit banking
- Catch sharing via sectors would be allowed, reducing the costs of exceeding a vessel's functional group catch allocation.
- Recreational fishing permits
    - Limited access for charter/party boats?

The purpose of this section is to discuss how a limited access program, common throughout many of our existing FMPs (see table below), can be applied to a place-based (rather than species-based) FEP. 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 might 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 cuts across multiple jurisdictions and may, in the end analysis, allow a vessel to fish for a species in its MU 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 the MUs that it is authorized to fish. Vessels that had fished in multiple MUs could also be authorized to fish in more than one MU, but vessels with no history of fishing in an MU 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 MU limited access permit would be able to fish for any species (subject to potential special situations below) that is available within the MU, subject to catch limits defined by Species Complexes. Thus, as species distributions, availability, and abundances change, vessels within defined MUs would be able to target those resources with their place-based limited access permit, subject to ecosystem catch limit specifications.

There may however be some special cases where the landings are highly valued, that require special permitting regardless of its energetic linkages to other stocks found in the EPU. Alternatively, a stock that has a low degree of energetic association with other EPU stocks may also be designated as requiring a separate limited access permit. In the first case of a highly-valued (price) species, a separate limited access permit based on previous permitting and participation in that fishery may be needed to prevent excess effort from targeting that one species due to its high value compared to other species in the EPU. Some examples where a special limited access program that differs from MU-based limited access could be sea scallops (value), American lobster (value), red crab (weak energetic association), bay scallops (weak energetic association), and surf clams/ocean quohogs (weak energetic association). Catch of all species by vessels having a special limited access permit would be monitored and count against the MU Species Complex catch specifications.

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 MU within the last 5 (qualifying period ???) years. A vessel may also qualify if it had landings of species reported to have been caught within the MU of a regulated species not requiring an existing limited access permit.
    b. Inactive or history: A vessel must have an existing limited access permit for a species that occurs within an MU, but not have landings that were derived from elsewhere during the qualifying period.
    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 MU.

2. **Permits**
    a. A standard limited access permit would be required to fish within the MU and the vessel could target any species not covered by a special exemption using any gear (subject to technical limits set by the MU 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 MU to fish for and land any species not covered by a special exemption. Vessels that are authorized to fish in more than one MU will need to qualify for and hold a standard limited access permit for EACH MU, 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 MU.
    b. No limits on length, HP, or GRT will apply (since catch limits will 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 MU permit holders may catch up to the Species Complex catch limits. Species Complex catch limits within an MU would be based on a) the EPU catch specifications and b) the proportion of EPU catches previously (qualification period?) made by vessels with a limited access authorization to fish in the MU. 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 MU. Overages will be subject to future adjustment through accountability measures.

Table 2. List of existing limited access permits and their characteristics that currently apply to fishing within a Georges Bank EPU.

Limited access permit and jurisdiction	Species which may be landed using permit	Permitted vessels (2015), Issued permits with Georges Bank EPU landings, Issued permits with no landings, and History permits	Qualification criteria and period	Top three overlapping[2] limited access permits
NE Multispecies (NEFMC)	Cod, haddock, yellowtail flounder, etc.	(e.g.) 400/300/100/50		
Monkfish (NEFMC/MAFMC)	Monkfish			
Small-mesh multispecies (NEFMC)	Silver hake, offshore hake, red hake		Under development	
Skates (NEFMC)	Little, winter, rosette, clearnose[3]		Pending	
Squid, mackerel, butterfish (MAFMC)	Illex and loligo squid, Atlantic mackerel, butterfish			
Summer flounder (MAFMC)	Summer flounder			
Sea Scallops (NEFMC)	Sea scallops			
Sea Scallops, General Category (NEFMC)	Sea scallops			
Surf clams/ocean quohogs (MAFMC)	Surf clams, ocean quohogs			
American lobster (NMFS/ASMFC)	American lobster			
Red crab (NEFMC)	Red crab			
Bluefin tuna (NMFS)	Bluefin tuna			
Atlantic sharks	Various sharks			
Etc.				

[2] Permits held in common by a single vessel.
[3] 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.

Total number of vessels with any limited access permit				

9.3 Catch Allotment/Allocation (Fishery Functional Groups)

[need to flesh out this as an example]

- Allocations made to permit holders in functional groups of species (i.e. a stock complex caught by gear type)
- A permitted vessel would receive an annual catch allocation of one or more functional groups that are caught by a Georges Bank fishery.
- Recreational catch allocations

9.4 Complete catch accounting (including all fish, mammals, reptiles, and invertebrates)

9.4.1 Integrated sea sampling and catch reporting

9.4.2 Mandatory Retention

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9.5 Technical measures

In addition to limiting and allocating catches for species complexes, a set of technical measures will be needed to manage selectivity (increasing yield-per-recruit while minimizing discarding) and minimize adverse environmental effects. Technical measures may also be needed to reduce fishing pressure on species in a stock complex that are particularly vulnerable to fishing, either due to low growth and fecundity characteristics or because fishermen will excessively target high valued species. These measures are not unlike those that are currently in use, but still allow enough flexibility for fishermen using their gear to target healthy stocks.

- Size- and species-selective gear
- Mandatory retention of marketable species
- Area closures to reduce impacts on spawning, habitat, and/or endangered or threatened species (see Section 9.7)
- Incentives to fish in low-impact, selective fisheries
- Measures to prevent excessive targeting of highest value and/or vulnerable species

9.6 Evaluate trends in ecosystem indicators and status (relative to reference points)

9.7 Spatial Management Measures for Habitat, Spawning, and Endangered/Threatened Species Protection – Draft Discussion Document 9

- Improvements in productivity through better habitat quality and survival of juvenile fish

1. Linkages between habitat attributes, managed species, and biological diversity (the conservation of which is a key component of EBFM).
2. Issues of spatial and temporal scale in our understanding of the role of that habitat mediates patterns and dynamics of fish populations.
3. Effects of fishing on habitat and habitat recovery-resilience.
    a. Current focus on sensitive and vulnerable habitats based on community recovery-resilience. That is, biologic habitats with long recovery times.
    b. We currently discount habitats with rapid recovery times (1 yr or less) for management attention but there is a potential overlap in temporal patterns of use and functional role for fishes (e.g., as shelter and immediate access to prey) and disturbances by fishing.
    c. Effects of natural disturbance on habitat recovery and resilience.
4. Addressing habitat conservation under EBFM
    a. Minimizing gear effects via conservation engineering.
    b. Addressing indirect and cascading effects of predator removal on biogenic elements of habitat.
    c. Minimizing gear effects via effort reduction.
    d. Use of year round closed areas for habitats with high sensitivity, long recovery times and low resilience.

e. Use of seasonal closures for habitats with low recovery times and high resilience but high functional role on a seasonal basis.

5. Approaches for developing alternatives
    a. Habitats within EPUs (based on grain size, oceanographic regime, observations)
    b. Identify functional roles of habitats for managed species.
    c. Identify ecological communities and other ecosystem roles.
    d. Identify ecological sensitivity and vulnerability to fishing disturbances for each EPU-habitat type based on functional role and community attributes.
    e. Analysis based on existing EFH, HMA, HAPC (and Deep Sea Coral) designations.
    f. Link to spatial attributes of managed species within each EPU.
    g. Identify gaps and redundancies.
    h. Draft decision rules to identify (preferred) alternatives.

9.7.1 Fishing impacts on ecosystem

Fishing fleets and communities with variable dependence, resilience fishing fleets characteristics, participation across multiple fisheries other human uses of EPUs, community vulnerability, tradeoffs/conflicts

9.7.2 Non-fishing impacts on ecosystem

Climate influences on the social-ecological system list current observations/impacts specific to EPUs/communities projected changes

9.7.3 Unmanaged and invasive species policies – Draft Discussion Document 12

- Special policies, such as imported bait and closed area effects

The New England Fishery Management Council does not have a "policy" on invasive species, but here's what I can pass along to steer you in the right direction.

1) Tunicates, Didemnum vexillum, are probably the most obvious example on an invasive species in our federal waters region. The tunicate is a gravel-associated mat-forming colonial animal that can smother other types of organisms and locally reduce benthic diversity. It's known to occur on both Georges Bank and Stellwagen Bank, where many of our fishermen operate. Tunicates co-occur with Atlantic sea scallops, which the New England Council manages, so tunicate presence sometimes comes up in discussions at meetings of our Scallop Plan Development Team or within industry and in the scientific community. Two related papers are attached.

2) Judith Pederson at MIT Sea Grant is an invasive species expert. You can track her down through these two links, and I'm pasting in some information from the MIT Sea Grant website.

http://seagrant.mit.edu/people_desc.php?usrID=314

http://seagrant.mit.edu/ecosys_health.php#mis

Dr. Pederson coordinates the Gulf of Maine Regional Ocean Science Initiative and compiled and edited the 2009 Gulf of Maine Strategic Ocean Science Plan. An international expert on marine invasive species, her research focuses on the "biopollution" of marine bioinvasions in near-shore and offshore areas of the Gulf of Maine and Georges Bank. In addition to her research over the past 20 years, Pederson has further contributed to water-quality monitoring, clean-up efforts in Boston Harbor and other areas of Massachusetts, and the disposal of contaminated marine sediments. Prior to joining MIT Sea Grant in 1995, Pederson worked as a coastal ecologist at the Massachusetts Office of Coastal Zone Management.

MIT Sea Grant provides information on marine invasive species through its Marine Bioinvasions site and through a collaborative regional site, New England Marine Invasive Species (NEMIS). In addition, MIT Sea Grant coordinates periodic (four assessments since 2000) Rapid Assessment Surveys (RAS) of marine non-native species in the Northeast. For each RAS, an international team of marine species experts is assembled to identify, document, and distribute information about both native and introduced species found at selected sites. The goals of these programs are to raise public awareness and provide approaches to prevent and mitigate the spread of invaders.

3) Another expert – Dr. Jenn Dijkstra at UNH has published papers on invasive species in the Gulf of Maine.

https://ccom.unh.edu/user/jdijkstra

https://ccom.unh.edu/user/387/publications

Dr. Jenn Dijkstra is a Research Assistant Professor in The School of Marine Science and Ocean Engineering and the Center for Coastal and Ocean Mapping. She serves on the New Hampshire commission for Coastal Marine Natural Resources and Environment. Her research interests include patterns and processes of biodiversity and biogeography, habitat structure, and introduced species. In these areas, her research focuses on 1) Biogeography of marine species, 2) Introduced species, 3) Biogenic structure and ecosystem function and 4) Integration of data collected by in-situ sampling and remote-sensing techniques to identify and characterize marine species assemblages. Dr. Dijkstra received a B.A. from the University of New Brunswick (Canada), a M.Sc. in Marine Biology from the University of Bremen (Germany) and a Ph.D. from the University of New Hampshire.

4) This is a state issue rather than a federal issue, but you might want to check in with the Maine Department of Marine Resources to find out more about the European green crab, Carcinus maenas, that has been extremely problematic there.

http://www.maine.gov/dmr/science-research/species/invasives/greencrabs/index.html

Also, you might want to look at Maine's lobster and crab bait information. Regulations were implemented to prohibit invasive species problems.

http://www.maine.gov/dmr/science-research/species/lobster/bait.html

5) Massachusetts has a Marine Invasive Species Program. This state also deals with green crab problems.

https://www.mass.gov/marine-invasive-species-program

6) Here is the Northeast Fisheries Science Center's invasive species webpage. We work with the science center on a regular basis.

https://www.nefsc.noaa.gov/ecosys/ecosystem-ecology/invasive.html

7) You might want to comb the NOAA Fisheries website for updates on invasive species tracking and control efforts. Here's one example that's problematic for our southern counterparts:

https://www.fisheries.noaa.gov/media-release/aquatic-nuisance-species-task-force-press-release-national-invasive-lionfish

8) Here are two other resources for you to check:

- The marine invasions lab at the Smithsonian: https://serc.si.edu/labs/marine-invasions-research/
- The National Ballast Information Clearinghouse: https://invasions.si.edu/nbic/collaborators.html.

9.8 Transition strategy to place-based FEP

- How and when do new changes occur?
- Gradual phase ins?
- Functional group catch allocations for NEFMC managed species as well as unmanaged stocks initially and later applies to all managed stocks?

10.0 Other Components of a FEP Performance Review (unfinished material placeholder)

10.1 Advisory Teams

Describe characteristics and function here.

10.2 Decision support

10.2.1 Performance metrics and analysis (unfinished material placeholder)

Evaluating the performance of a management plan relative to stated goals and objectives post-implementation is a key component of IEA process and the adaptive management cycle.

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10.2.2 Management Strategy Evaluation

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 17. Feeding guilds and Species Complexes of Georges Bank EPU species.Table 17). 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 3. 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 completion 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.

10.2.3 Candidate Operating Models – strengths and weaknesses

10.2.3.1 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.

10.2.3.2 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

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no feedback between prey consumption and predator growth in Hydra. Species grow regardless of whether they consume sufficient prey.

10.2.3.3 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..

10.2.4 Integrated Ecosystem Assessment

- A broad summary of trends in various biological, oceanographic, economic, and social indicators.

10.2.5 Ecosystem Risk Assessment

- Expert opinion indicated the level and immediacy of risk factors that can affect the ecosystem and how well management will achieve its objectives.
- Balance conservation and social objectives (http://s3.amazonaws.com/nefmc.org/150818.Risk.Policy.Road.Map.Draft.pdf) (Tool: Risk assessment; Tool: stakeholder process based MSE)

10.2.6 Management strategy evaluation (MSE) – Draft Discussion Document 11

- Pre-plan development – objectives evaluation and models
- Simulation and evaluation of management via operating models – Draft Discussion Document 3
- Post plan – standard process for plan amendments

10.3 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.

10.4 Biological and environmental sampling (Data Collection and Monitoring)

- Gaps in mandatory data collection
- New ecological data

- Electronic monitoring
- Research set-aside (RSA) program – a portion of allowable catch limit is reserved for supporting management-related research

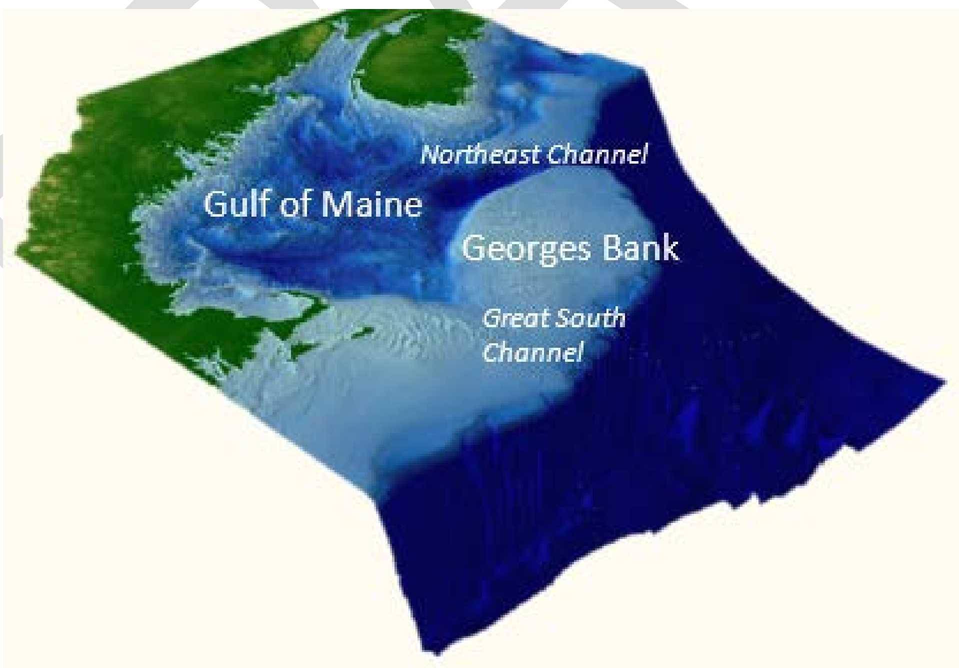
10.5 Research evaluation and prioritization

10.6 Cooperative and gear effects research

11.0 Description of the Georges Bank Ecosystem

Georges Bank is a shallow-water, highly productive submarine plateau located off the New England coast (Figure 3.1). 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; Figure 19). 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.

Figure 12. 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).

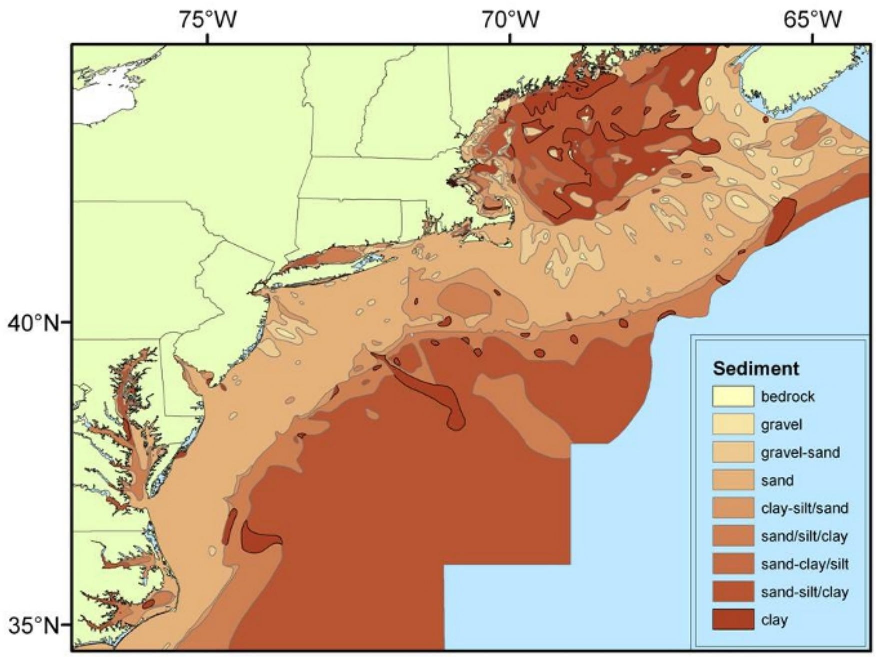
11.1 Benthic Habitats

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; Figure 20). 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).

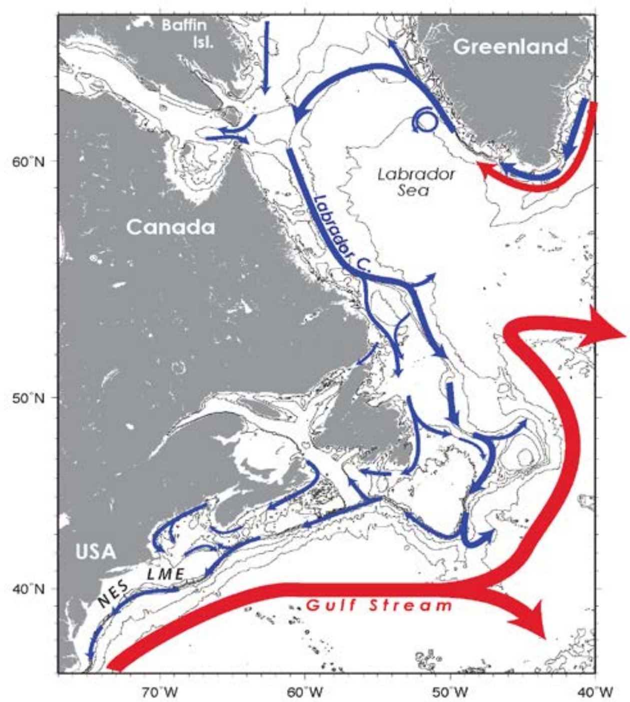
Figure 13. Sediment distribution on the Northeast US Continental Shelf.



11.2 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 (Figure 20). 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.

Figure 14. 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.

11.3 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 (Figure 22).

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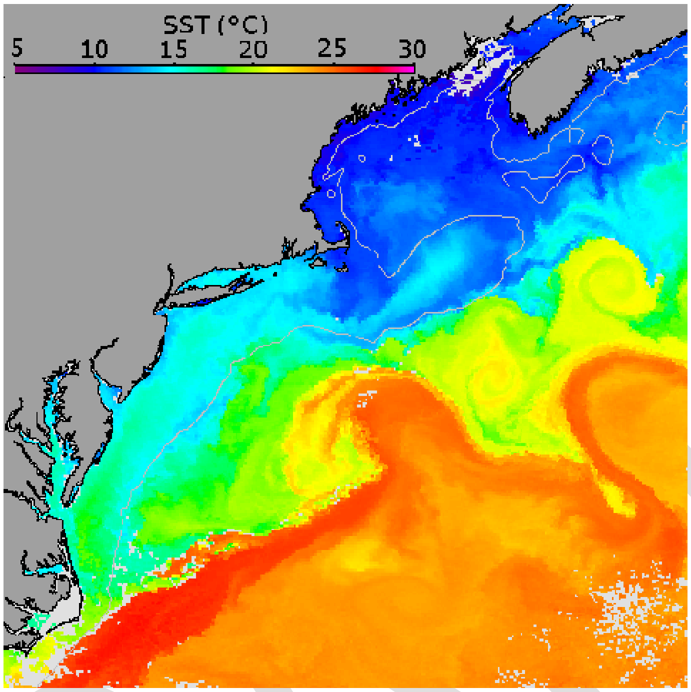
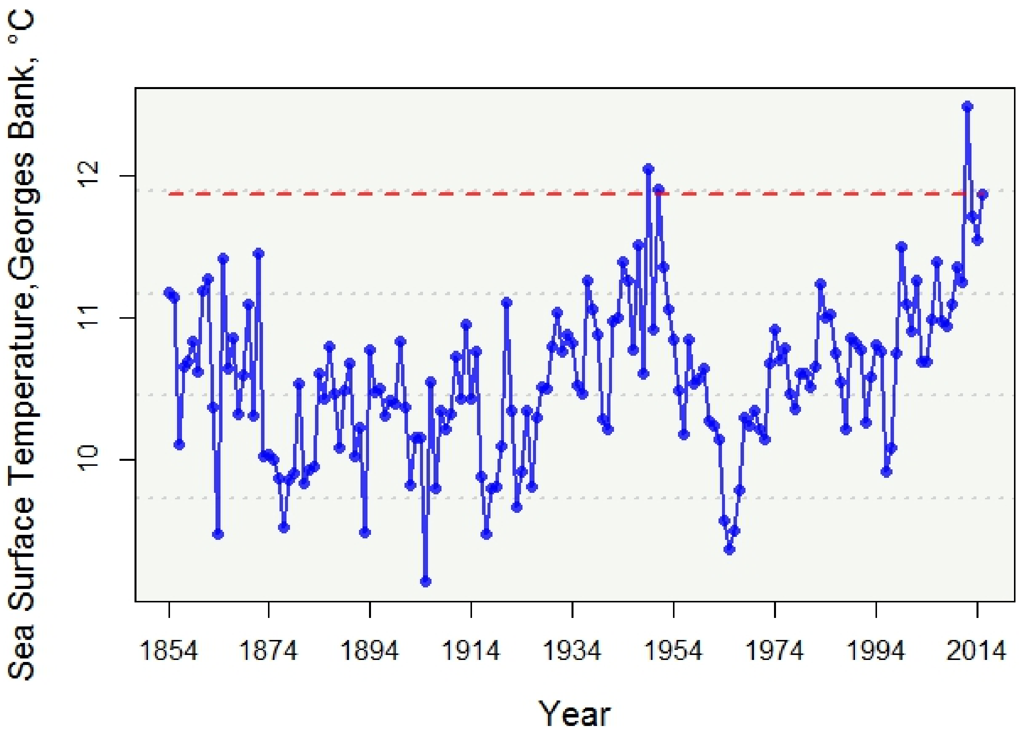
Figure 15. Satellite image of fall surface water temperature patterns on the Northeast U.S. continental shelf. Cooler temperatures are represented by darker colors shading to blue. Warmer temperatures, such as those associated with the Gulf Stream are represented by the warmer colors shading to red.



Temperature in the NES LME has varied substantially over the past 150 years (Figure 23). 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.

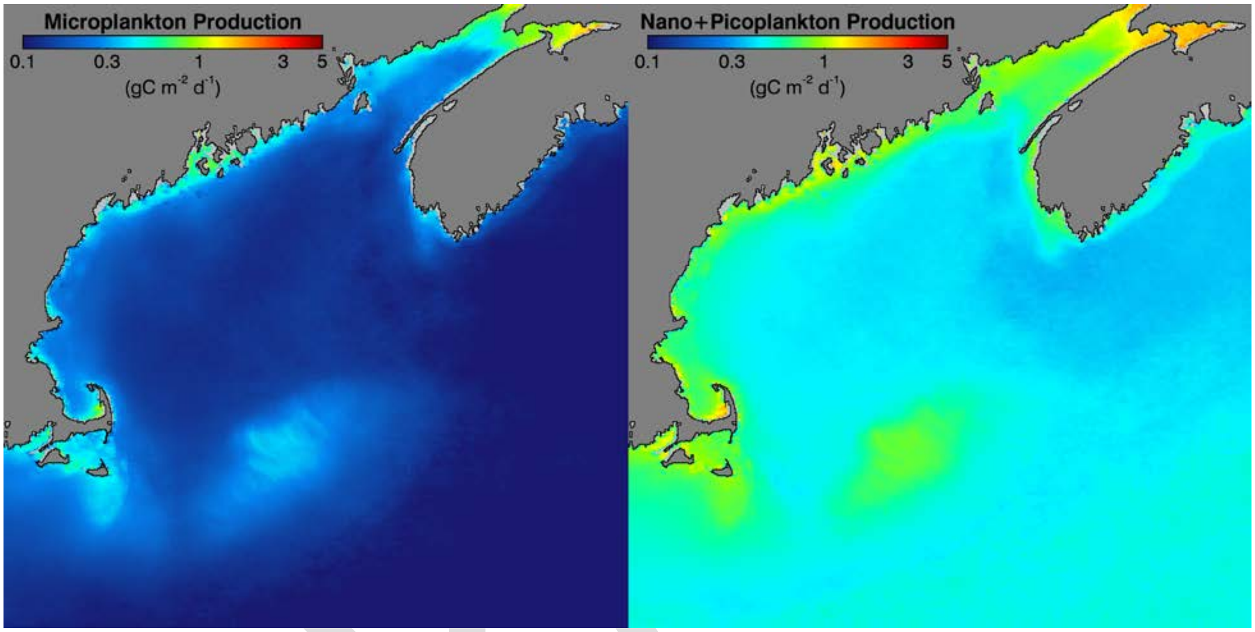


11.4 Production Characteristics

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 □) and nano-picophytoplankton (<20 □) show important differences between production on Georges Bank relative on in the adjacent Gulf of Maine (Figure 24). 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.

Figure 17. Annual mean primary production (gC m-2d-1) from microplankton (left) and nano-picoplankton (right)

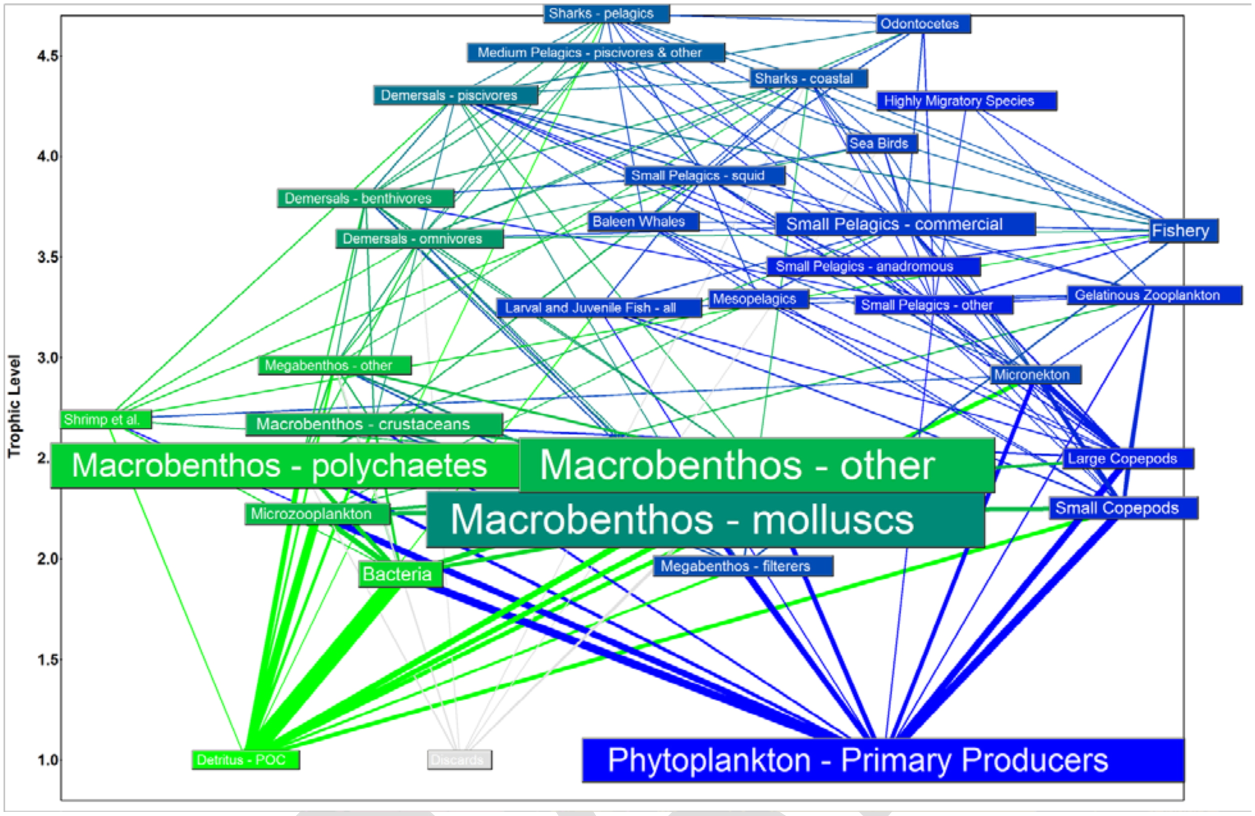


11.5 Georges Bank Food Web

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 25. 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 6.0 in the context of a broader discussion of ecosystem models for management.

Figure 18. Depiction of Georges Bank food web employed in the Link et al. (2008).



11.6 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.

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11.7 Summary of characteristics and management status of species with the Georges Bank EPU

Table 4. 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

Species	*Scientific Name*	Management authority	FMP	Total q-adjusted biomass	Species Complex	Trophic level	Adult body size	Primary Offshore Habitat	Preferred Depth Range (m)
14. American Lobster	*Homarus americanus*	ASMFC	Lobster	16.68	Benthivore				
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				

Species	*Scientific Name*	Management authority	FMP	Total q-adjusted biomass	Species Complex	Trophic level	Adult body size	Primary Offshore Habitat	Preferred Depth Range (m)
29. Octopus		Unmanaged	NA	#N/A	Benthivore				
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/NEFMC	NE Skate Complex	192.42	Macroplanktivore	4.3	< 60		20-300

Species	Scientific Name	Management authority	FMP	Total q-adjusted biomass	Species Complex	Trophic level	Adult body size	Primary Offshore Habitat	Preferred Depth Range (m)
44. White Hake	*Urophycis tenuis*	NEFMC	NE Multispecies	0.15	Macroplanktivore	4.2	20 - 40	Fine sediments, mixed and rocky habitats	30-400
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	

Species	*Scientific Name*	Management authority	FMP	Total q-adjusted biomass	Species Complex	Trophic level	Adult body size	Primary Offshore Habitat	Preferred Depth Range (m)
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
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

Species	*Scientific Name*	Management authority	FMP	Total q-adjusted biomass	Species Complex	Trophic level	Adult body size	Primary Offshore Habitat	Preferred Depth Range (m)
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	
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		

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Table 5. 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												

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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
39. Shortfin squid	Macroplanktivore													X
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													

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
55. Silver hake, < 40 56.	Macrozoo-piscivore													
57. Blueback Herring	Mesoplanktivore			X						X				X
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		

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
75. Bluefish	Piscivore		X										X	
76. Spiny Dogfish > 60 cm	Piscivore		X		X		X					X		
77. White Hake, > 40	Piscivore		X		X		X					X		
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													

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

Table 6. 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**	

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Table 7. 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 8. 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**	

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Table 9. 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 10. 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		

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Table 11. 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	Feeding guild	
Management/species	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 12. 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	Feeding guild					
Management/species	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**	

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Table 13. 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**	

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Table 14. 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**	

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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 **pelagic recreational fishery.**

Total biomass, '000 mt Management/species	Feeding guild 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 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 consumed by **protected species.**

Total biomass, '000 mt Management/species	Feeding guild 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**		

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12.0 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.

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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

13.0 References Cited

Citations go here???

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