

## Northeast Fisheries Science Center Strategic Plan

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### ***Introduction***

The Northeast Fisheries Science Center conducts a multidisciplinary data gathering, sampling, processing, and research effort focused on developing ecosystem-level knowledge, sustainable aquaculture, and a better understanding of human influence on the ocean environment.

We primarily study the Northeast Continental Shelf Large Marine Ecosystem (LME), comprising about 100,000 square miles of the northwest Atlantic. It is one of the world's most studied and commercially exploited LMEs. The waters are temperate, structurally complex, and characterized by marked temperature and climate changes, winds, river runoff, estuarine exchanges, tides, and circulation regimes, and functions supporting a diversity of sea life.

Each region within the NOAA's National Marine Fisheries Service (NOAA Fisheries Service) has unique features and challenges. In the Northeast, we are marked by our place in the history of fisheries science, our complexity, and the Northeast's strong cultural identity as a place founded on fishing. These markings are indelible and deep. They circumscribe how we can achieve our desired goals within this strategic plan.

This plan is grounded in more than 140 years of marine scientific inquiry by federal fishery scientists in the Northeast. In this plan, we look to the future, toward a science program that can support managing ocean use on an ecosystem level. The Northeast is among the few places where the data and tools are readily available to support management on that scale.

To do so, the plan relies on both preserving our core capabilities and on building a broad-based science program.

We consider a core capability or activity to be one that is essential to preserving regularly delivered services and products of highest priority to the agency. Data collections to enable species assessments are one example of this (see Table 1). Although all other activities are non-core, they are important. In fact, non-core activities may be urgent and address emerging high-priority issues of concern to the agency, as well as research to improve efficiency and reliability of our science and data products.

All of our activities support the mission and objectives of the agency and Center. Together they form a broad platform that we intend to strengthen and improve. To do so, the plan relies on preserving our core capabilities and building a broad science program. This allows us to better support multi-level management of ocean use, to be responsive to legislative and treaty mandates, and to leverage assets with our multiple research partners in the region.

We will revisit this plan every five years to evaluate accomplishments and progress toward these overarching goals.

This plan describes the broad research goals and foci for our science program but does not detail the infrastructure and support services needed to implement it. These are briefly described at the end of this document, and will be fully addressed separately in our implementation process. To

accomplish mission, we rely on technical and support expertise, and we will continue to develop a multifaceted, highly functional workforce.

Our science effort is therefore organized around four research themes (for detail, see Table 1):

- Monitor, value, and assess fish, invertebrate, and marine mammal populations, fisheries, marine ecosystems, and the natural and human communities associated with them
- Understand and forecast effects of environmental change (including climate change) on marine ecosystems, coastal communities and economies
- Describe and assess the role of habitats in ensuring healthy marine ecosystems; healthy populations of fish, invertebrates, marine mammals, and sea turtles; and resilient coastal communities and economies
- Understand anthropogenic, ecological, and biological factors affecting development of sustainable marine aquaculture on the Northeast continental shelf

<b>Table 1. Summary of 13 major research foci for the NEFSC grouped into four themes</b>
<b>Theme 1: Monitor, value, and assess fish, invertebrate, and marine mammal populations, fisheries, marine ecosystems, and the natural and human communities associated with them</b>
Maintain data and sample collection and processing, and analytical capabilities to support single-species, multispecies, and ecosystem assessments for fish, invertebrates, marine mammals, sea turtles and human activities (Core Activity)
Provide data, analyses, assessments, information, and scientific support to NMFS, its partner federal agencies, fishery management councils and commissions, and international treaty organizations (Core Activity)
Improve, enhance, or expand fish, invertebrate, sea turtle, and marine mammal stock assessments, impact analyses, and biological and socioeconomic data collections to meet regulatory requirements and to implement an integrated ecosystem monitoring program
Conduct integrated ecosystem assessments and support ecosystem-based management within the Northeast LME to meet emerging management needs and mandates
<b>Theme 2: Understand, forecast, and mitigate effects of environmental change (including climate change) on marine ecosystems, coastal communities, and economies</b>
Monitor and understand the effects of multiple and cumulative anthropogenic and natural changes on marine ecosystems and develop mitigation measures or tools where appropriate
Understand ecological interactions within and between species
Forecast effects of environmental change on fish, invertebrate, marine mammal, and sea turtle species, and human communities
Conduct research on bioextraction as a means of removing excess nutrients from eutrophied waters
<b>Theme 3: Describe and assess the role of habitats in ensuring healthy marine ecosystems; healthy populations of fish, invertebrates, marine mammals, and sea turtles; and resilient coastal communities and economies</b>
Assess and evaluate the importance of specific habitat types for fish, invertebrate, turtle, seabird, and marine mammal populations
Evaluate and forecast impacts of human activities including fishing on habitats of fish, invertebrates, marine mammals, and sea turtles
Provide information and analyses to support coastal planning
<b>Theme 4: Understand the anthropogenic, ecological, and biological factors affecting development of sustainable marine aquaculture on the Northeast continental shelf</b>
Apply the contemporary tools of biotechnology and the biomedical field, including DNA technology, to applied research on the health of aquacultured organisms and their interactions with the environments in which they are cultured and with other ecosystem components
Conduct research on developing aquacultural methods for marine mollusks and finfish

***Background and Purpose***

The promise of ecosystem-based management (EBM) is that it delivers more benefits than can be derived when each part of the system is managed separately. This integrated management approach also compels us to deliver an integrated understanding of how components of complex human and ocean systems are linked, or “coupled.”

We are ready to take the next steps to conduct NEFSC science program under a more holistic framework devised to support a broader ecosystem approach to both understanding and managing marine resources that fall within NOAA’s authorities. However, we also need to maintain current capabilities and approaches to ensure that existing regulatory and legislative requirements are met.

In this plan, we summarize our transition toward an ecosystem-based science effort. We describe not our future direction, and state our intent to meet our ongoing regulatory and legislative requirements over the next five years. The plan will guide priority-setting and decision-making within NEFSC for a variety of purposes, including resource allocation.

***National Priorities for Ocean Research***

*“U.S. ocean and coastal resources should be managed to reflect the relationships among all ecosystem components, including human and nonhuman species and the environments in which they live. Applying this principle will require defining relevant geographic management areas based on ecosystem, rather than political, boundaries.”*

**U.S. Commission on Ocean Policy (2003)**

NOAA’s Ecosystem Goal Team characterized ecosystem-based management as follows: It is adaptive, and geographically specific, or “place-based.” It accounts for uncertainties, considers multiple external influences, balances diverse societal objectives, recognizes humans as an integral part of the ecosystem, and treats marine ecosystems as coupled human-natural systems.

Ecosystem-based management provides an integrated framework for the sustainable delivery of ecosystem goods and services (Figure 1). Humans derive a broad spectrum of ecosystem services from the sea, ranging from food to buffering the effects of climate change and variability. We need to appreciate the important services derived from marine ecosystems and to recognize the diverse and cumulative impacts of human activities in these systems to forge a sustainable future.

NOAA Fisheries Service plays a lead role in developing scientific advice related to provisioning services (fisheries and aquaculture), and in research and advisory activities directly relevant to provisioning, regulating, supporting, and cultural and amenity services. This advice relies on understanding the drivers of key ecosystem services, assessing their status in relation to management reference points, and considering impacts to the long-term viability of these services (Figure 2).

Our research strategy is to understand ecosystem structure and function, the critical dimensions of coupled human-resource systems, and the role of environmental change in system dynamics. This

ecosystem services perspective provides an overarching framework for designing a transdisciplinary research program that addresses broad societal needs and goals.

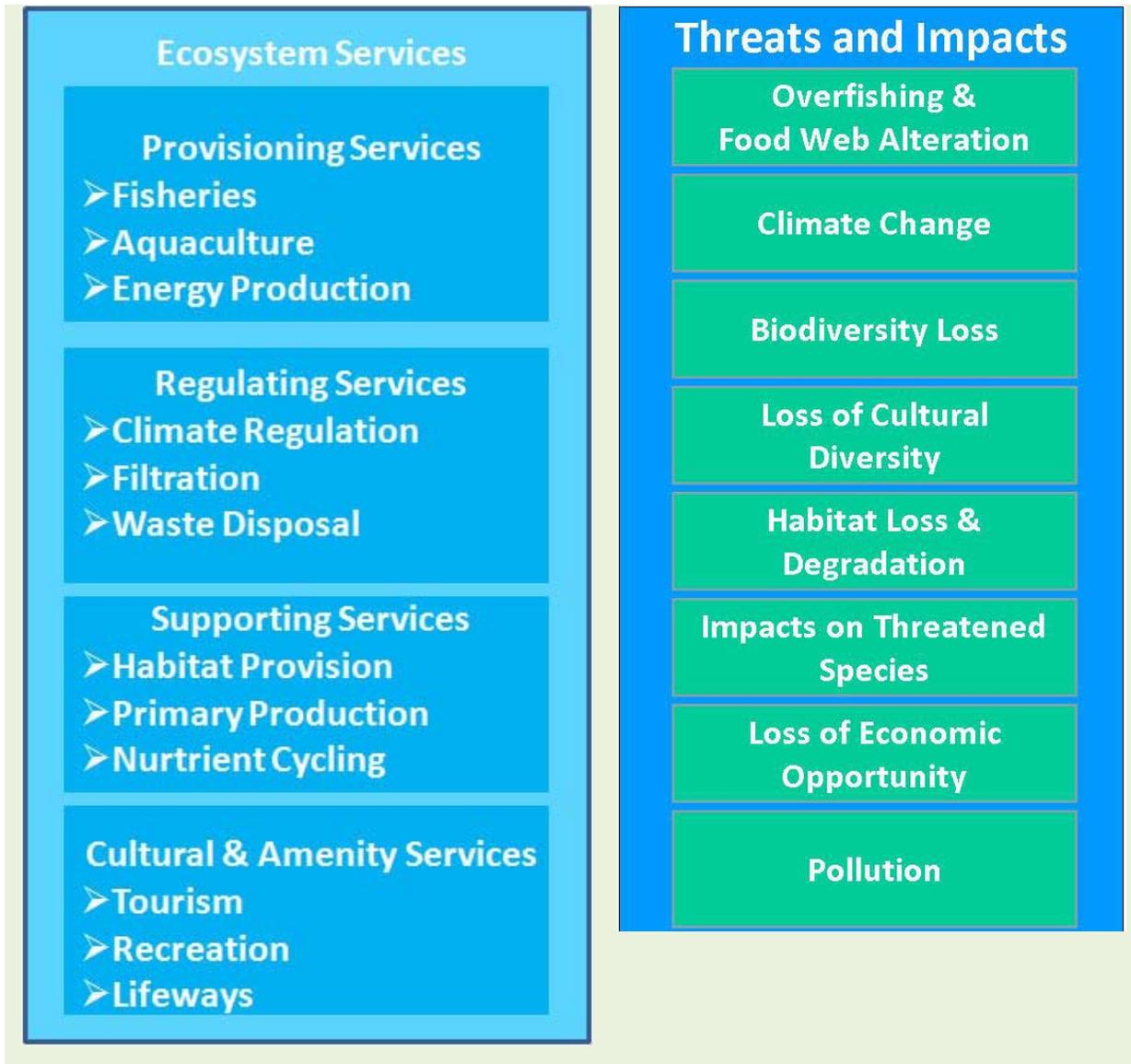


Figure 1. Key ecosystem good and services derived from the ocean

Figure 2. Factors affecting viability of ocean ecosystem services

Collectively, the specification of relevant ecosystems services that fall within the remit of NOAA Fisheries Service and assessment of impacts and associated risks to these services provides a template for identifying research strategies required to meet emerging challenges in the 21<sup>st</sup> century.

***Role of the Northeast Fisheries Science Center (NEFSC)***

The mission of the Northeast Fisheries Science Center is to:

*Conduct ecosystem-based research and assessments of living marine resources, with a focus on the Northeast Shelf, to promote the recovery and long-term sustainability of these resources, and to generate social and economic opportunities and benefits from their use.*

The NOAA Fisheries Service was born in the Northeast when Spencer Baird, the first U.S. Fish Commissioner established a field station at Woods Hole, Massachusetts. Still headquartered on the original 19th Century site of the first permanent laboratory, the Northeast Fisheries Science Center also includes specialized research facilities in Maine, Rhode Island, Connecticut, New Jersey, and at the Smithsonian Institution in Washington, D.C. These science programs were started by predecessor agencies at these facilities in the 1930s, 1940s, 1960s, and 1990s. Together with the Woods Hole Laboratory, they account for the shape of today's NEFSC.

Our resource issues are complex. Of the nation's 45 overfished marine stocks, about one-third occur in the Northeast. More than a dozen species of endangered or threatened marine mammals and sea turtles, and anadromous fish are found here, including one of the world's rarest large whales, the North Atlantic right whale, and the iconic Atlantic salmon.

Our resource management arena is also complex. The center provides advice to two of the nation's fishery management councils and one interstate fishery management commissions. In New England, a major plan amendment takes two to three years to implement, and the final document averages more than 1,000 pages. In the Northeast, you'll find a wide variety of gear types, vessels sizes, communities, and dependence on fishing for core income.

Within this environment, our Center has maintained a long-standing commitment to research, assessment, and monitoring at all levels in the ecosystem from phytoplankton to apex predators, protected species, and human communities. Our research encompasses climate science, physics, ecology, and the social sciences; process-oriented ecosystem research; and extensive marine population dynamic, socioeconomic, and ecosystem modeling in support of management. Our research also includes extensive collaboration with external research partners and fishermen.

The primary responsibility of the NEFSC is to provide scientific data, sampling, analysis, and technical advice to a variety of entities for use in understanding and managing marine resources. These entities include our own agency, other federal and state agencies, fishery councils and commissions, research colleagues, nongovernmental organizations, and national and international treaty organizations in which the U.S. participates, and the fishing industry (both commercial and recreational).

While most of our focus is on fisheries and protected species, our work is also used to evaluate nonfishery marine activities. For example, we evaluate ocean areas for ecological, fishery, and protected species sensitivities when states, the Bureau of Ocean Energy Management, or the U.S. Navy seek advice about the effects of their activities.

To fulfill U.S. science obligations to organizations that influence use of fish and marine mammals across international boundaries, NEFSC staff participate in a variety of scientific working groups and advisory bodies. These include treaty organizations such as the International Whaling Commission, the North Atlantic Salmon Commission, the International Council for Exploration of the Sea, the North Atlantic Fisheries Organization, and the International Commission for Conservation of Atlantic Tunas.

Uniquely situated within our Center is the National Systematics Laboratory (NSL), an internationally important resource at the Smithsonian Institution's National Museum of Natural History. The NSL researchers study marine biodiversity. They describe and name new species, revise existing descriptions and names, and document evolutionary systematic relationships based on new information. The staff members write taxonomic monographs, which are scholarly documents that identify, describe, and catalogue the diversity of marine organisms with commercial or ecological importance. They also create various aids to identification, including descriptions of new species and of the development of known species, and taxonomic keys.

NSL scientists serve as curators for the components of the Smithsonian's National Collections for which they are recognized experts. These components include several families of marine fishes and major taxonomic subgroups of invertebrates including sponges, cnidarians, crustaceans, and mollusks. As adjunct faculty at various universities, NSL scientists also supervise research by graduate students on a variety of topics.

For some species we share responsibilities with other agencies. For example, our agency has the lead for conserving endangered Atlantic salmon during their marine phase and for ensuring connectivity with ocean at dam passage facilities, complementing U.S. Fish and Wildlife Service hatchery-based programs for Atlantic salmon. Similarly, NMFS is responsible for conservation of sea turtles during their marine phase and for mitigating bycatch of sea turtles and seabirds, again complementing U.S. Fish and Wildlife Service's programs on those species.

The NEFSC has strong ties to NOAA's Cooperative Institute for the North Atlantic Region which facilitates long-term collaborations among NEFSC and university researchers, and helps train the next generation of the scientific workforce through student involvement and special educational programs. The NEFSC also maintains direct working relationships with a variety of academic institutions to further our research mission.

The research and advisory activities of the Center can be linked directly to each of the four Ecosystem Service categories described in Figure 1 and associated threats to sustainability related to natural and anthropogenic drivers. Human activities related to the latter can, in principle, be controlled or modulated through management actions to achieve sustainability. Much of the Center's research is designed to address this critical issue.

### **Research Themes**

***Research Theme 1: Monitor, value, and assess fish, invertebrate and marine mammal populations; fisheries; marine ecosystems; and the natural and human communities associated with them***

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The primary responsibility of the NEFSC is to provide quality scientific data, sampling, analysis, and technical advice to regional, national, and international entities that study, manage, and allocate marine resources. These products are delivered in a variety of forms. Demand for these products is increasing, as is the complexity they are expected to account for and the variety of ways in which users want or need to receive them.

The NEFSC has a long-standing commitment to ecosystem monitoring in order to gather data and observations needed to develop these products. These are essential for current work, and even more essential as we develop models that focus on a broader array of environmental and human processes to pave the way for ecosystem-based management in this region.

The first two research foci within this theme are our 'core' activities, representing work the NEFSC will continue under the most restrictive budget scenarios. The final two foci in this theme address enhancements to our core work, moving us toward integrated ecosystem-based products. Our ability to advance in these areas will depend on availability of new funding resources and overall research priorities.

#### **Research Foci for Research Theme 1**

- ❖ Maintain data and sample collection and processing, and analytical capabilities to support single-species, multispecies, and ecosystem assessments for fish, invertebrates, marine mammals, sea turtles, and human activities (Core Activity)

The NEFSC has a long-standing, multifaceted observing program conducted from a number of platforms including aircraft, research ships, and fishing vessels. Many of these activities were initiated decades ago with an explicit ecosystem focus and provide an extremely data-rich environment for supporting management and advisory requirements.

These monitoring programs collect information essential for assessments of fish, invertebrate, and protected species including abundance and demographic characteristics, the effects of human activities, and social and economic considerations. Core monitoring and collection efforts include:

- The long-running NEFSC bottom trawl survey that collects oceanographic, environmental, and biological data essential to stock assessments and development of multispecies and ecosystem assessments
- Cooperative research with industry to conduct scientific surveys, pilot specialized surveys, and improve fishery monitoring
- Ship-based and aerial sighting surveys for protected species, primarily marine mammals
- Dredge surveys for high-value benthic invertebrates such as sea scallops
- Hydroacoustic surveys for pelagic fishery resources
- Plankton surveys that collect data on changes at the base of the food web
- Coordinated processing of biological samples taken from specimens and used to estimate age, predation, and reproductive characteristics of harvested fish stocks
- Animal tracking networks using telemetry and passive acoustics

- Fishery observation through the Northeast Fishery Observer Program, which collects biological samples, as well as landings, bycatch, gear, and fishing practice information on commercial vessels during fishing trips
- Surveys, oral histories, ethnological interviews, and focus groups that gather economic and social data from commercial and recreational fishery participants, and about fishing communities

We are evaluating these core monitoring activities and new technology that could make them more efficient and cost-effective. We will continue to develop an integrated ecosystem survey design and implementation strategy. To do today's work and to prepare to support the complex analyses demanded in an ecosystem-based management and modeling we must maintain, modernize, and improve information technology.

In the coming years, the NEFSC will:

- Strengthen fundamental linkages among critical regional data sets to improve the efficiency of analytic procedures
  - Expand and modernize fishery-dependent data collection systems and move toward more electronic data capture; these advances are essential to achieving data integration
  - Invest in modernizing the IT infrastructure to improve data delivery systems and thereby expand usefulness of these data for a variety of applications, including visualizations and interactive
- ❖ Provide data, analyses, information, assessments, and scientific support to NMFS, its partner federal agencies, fishery management councils and commissions, and international treaty organizations (Core Activity)

The NEFSC produces stock assessments for 57 fish and invertebrate stocks on the Northeast Continental Shelf, for 27 cetacean and 3 pinniped stocks in the North Atlantic, Gulf of Mexico and Caribbean, and for 5 species of sea turtles. We provide profiles for 177 key communities affected by Northeast fishery management plans as well as community, vessel, and processor level analyses related to more than 1,700 communities, 5,000 vessels and 30 processors.

These assessments include evaluations of impacts of human activities on both protected and non-protected species. They are considered by fishery managers in making decisions about recovering protected species, and by NMFS when completing required NEPA, ESA, and MMPA evaluations.

Our stock assessment and social scientists participate in 14 plan development teams for existing federal fishery management plans and on a number of working groups that cover coastal species managed by the ASMFC. Center scientists from various disciplines are represented on the Scientific and Statistical Committees of both the New England and Mid-Atlantic Fishery Management Councils. Our scientists also routinely review the scientific content of fishery and protected species management documents, such as fishery management plan actions and biological opinions.

Center scientists support international management, contributing scientific and technical work to the International Whaling Commission, North Atlantic Salmon Conservation Organization, and the Northwest Atlantic Fisheries Organization. Continuation of these core services is vital to meeting U.S. international science and management responsibilities.

As members of the broader scientific community, Center scientists publish extensively, review scientific products and publications as individual peer reviewers, serve as scientific panel members, and on editorial boards. Sharing our scientific results and expertise with the broader scientific community and ensuring the quality of products and publications produced by other scientists are vital components of NEFSC's scientific responsibilities.

These activities will become broader and more complex as the New England and the Mid-Atlantic Fishery Management Councils move toward ecosystem-based fishery management over the next five years. Both councils have asked the NEFSC to contribute to the development of fishery ecosystem plans (FEPs) and this work is now in progress. Fishery ecosystem plans describe what's known about ecosystem structure, function, and status as a prelude to identifying potential management considerations and strategies.

- ❖ Improve, enhance, or expand fish, invertebrate, sea turtle, and marine mammal stock assessments, impact analyses, and biological and socioeconomic data collections to meet regulatory requirements and implement integrated ecosystem monitoring program

The NEFSC intends to improve assessments and, if possible, to expand the number of populations surveyed through technological innovation and adoption of more efficient, integrative sampling designs.

NMFS has developed stock assessment improvement plans for fish and invertebrates, sea turtles and marine mammals. These plans outline the types of information needed in assessments at increasing levels of specificity or confidence, and provide a ranking system for stock assessments that includes maintaining existing levels of information and elevating stock assessments to national standards of excellence.

To advance assessments we intend to:

- Extend single-species assessments by explicitly incorporating into them ecosystem considerations such as multispecies interactions and environmental effects, fisheries oceanography, and spatial and temporal dynamics
- Use extended single-species assessments as a springboard to more integrative and holistic ecosystem assessments
- Maintain and where feasible, improve collection of the data required for stock and socioeconomic assessments
- Increase information on marine mammal abundance trends, foraging habitat, fine scale distribution, and behavioral responses of marine mammals to stressors
- Strive to elevate marine mammal assessment quality to meet NMFS' national standards of excellence for all stocks in our area of responsibility

- More thoroughly evaluate the impacts of human activities other than fishing on marine species

To enhance our observational capabilities, NEFSC has recently invested in advanced technologies for visual and acoustic observations. We will apply these technologies to:

- Augment and complement net and dredge-based sampling programs with camera-based systems for observing plankton and benthic communities
- Automate processing of digital images and other samples to improve throughput
- Evaluate and improve our ability use hydroacoustic methods to support stock assessment and ecosystem monitoring
- Evaluate the potential for new technologies to serve as research or monitoring tools including animal telemetry systems, passive acoustic arrays, autonomous underwater vehicles, and gliders

The evolving NEFSC Integrated Ecosystem Monitoring initiative will lay the groundwork for a new sampling strategy to support ecosystem-level analyses. Through this strategy we will:

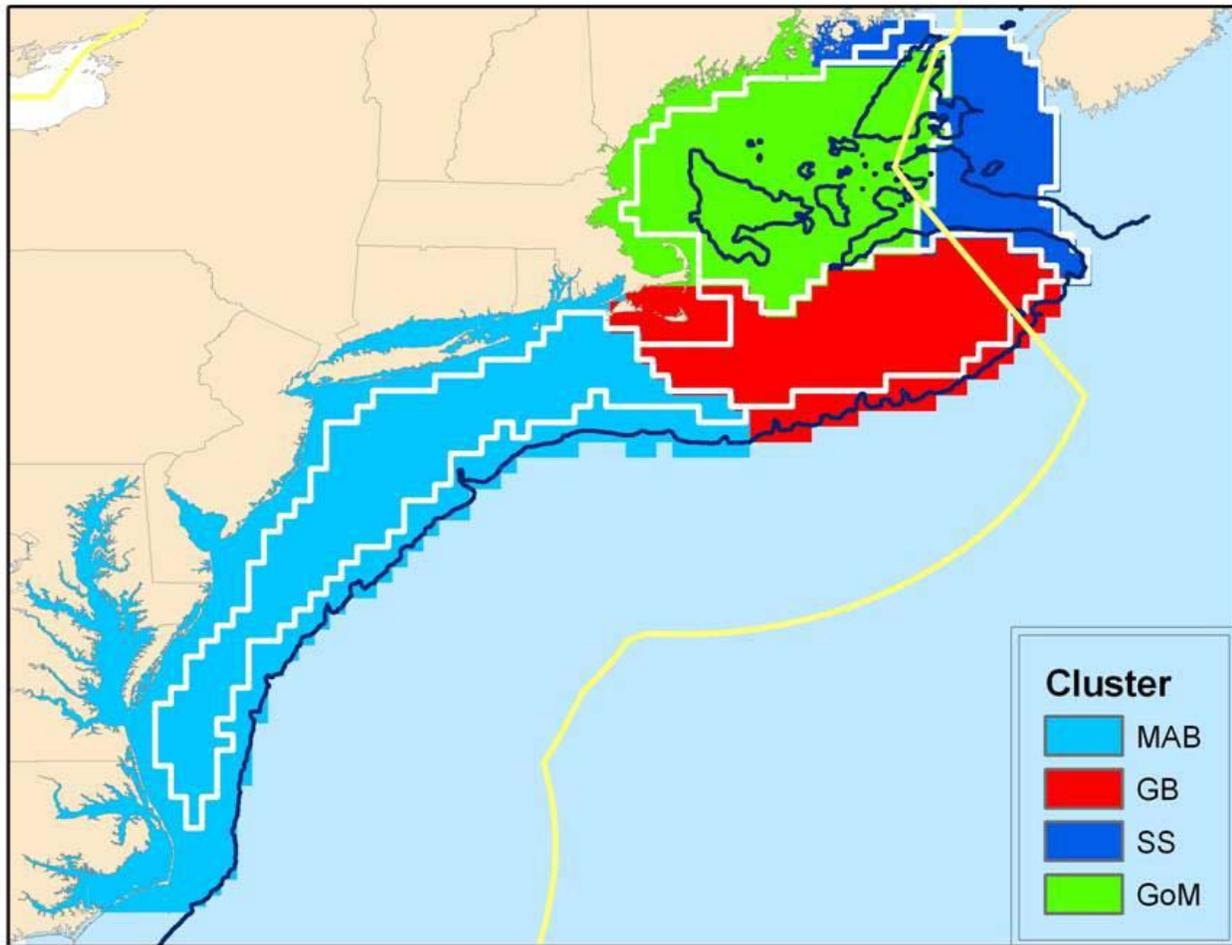
- Evaluate spatial and temporal domains for sampling
- Directly consider the need for population, multispecies, and ecosystem models
- Develop key ecosystem indicators that will help determine which, and at what scale, observations need to be made
- Enhance and expand ongoing social and economic surveys of fishers and fishing communities

- ❖ Conduct integrated ecosystem assessments and support ecosystem-based management within the Northeast LME to meet emerging management needs and mandates

Managing complexity will be the defining issue for developing management advice in an ecosystem context, requiring new approaches and ways of thinking.

To develop integrated management plans for defined ecological regions we must consider all the species within those regions, necessarily involving a change from single-species plans. The NEFSC has identified four major ecological production units on the Northeast Continental Shelf as a starting point for further consideration of place-based management (Figure 3).

An integrated management plan requires integrated ecosystem assessments (IEAs), the synthesis and analysis of all available information on relevant physical, chemical, ecological and human processes in relation to specified ecosystem management objectives. It effectively provides a counterpart to single-species stock assessments for ecosystem-based fishery management.



**Figure 3.** The production units for the Northeast Continental Shelf LME were devised through analysis of physiographic, oceanographic, and lower trophic level processes. MAB = Mid Atlantic Shelf, GB = Georges Bank, SS = Scotian Shelf, GoM = Gulf of Maine

An IEA provides an efficient way to summarize the status of ecosystem components, to screen and prioritize potential risks, and to evaluate alternative management strategies against a backdrop of environmental (e.g., temporal and spatial) variability. It also provides a way to evaluate tradeoffs in management objectives among potentially competing ocean-use sectors in support of coastal zone planning.

To ensure we can evaluate ecosystem status for management purposes, the NEFSC will:

- Develop an IEA for the Northeast Continental Shelf
- Develop and improve ecosystem indicators of fishing and climate impacts necessary for advancing multispecies and ecosystem assessments for fish, invertebrate, and marine mammal populations
- Advance ecosystem indicator assessment and forecasting to provide a means for assessing management efficacy
- Carry out or take advantage of experiments that allow investigation of impacts of stressors on particular ecosystem components or processes

***Research Theme 2: Understand, forecast, and mitigate effects of environmental change (including climate change) on marine ecosystems, coastal communities, and economies***

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#### **Research Foci for Research Theme 2**

- ❖ Monitor and understand the effects of multiple and cumulative anthropogenic and natural changes on marine ecosystems, and develop mitigation measures or tools where appropriate

There have been significant changes in the structure of the marine environment on the continental shelf off the northeastern United States in recent decades. These changes have affected the oceanography of the continental shelf and have influenced the abundance and distribution of fish, invertebrates, marine mammals, sea turtles, and seabirds. They also have implications for human communities that depend on marine resources. The NEFSC must continue to monitor and understand these changes in the Northeast LME in order to advise management bodies striving to mitigate their ecological, social, and economic impacts. To better inform management, the NEFSC will:

- Identify key threats to the ecosystem services (see Figure 2) in the region
- Examine trends in climate indicators and model these effects in the region at the population and community (human and natural) levels
- Develop models that allow us to better evaluate the consequences of multiple impacts, evaluate potential mitigations, and assess cumulative effects

- Evaluate fishery monitoring strategies relative to science, management, and compliance, implementing improvements as appropriate and cost-effective.

Developing fishing gear and practices that are more selective for target species can lessen undesired effects of fishing. The NEFSC will continue to use cooperative research with outside researchers and fishing professionals to:

- Develop and test new gear designs that reduce disturbance or damage to ocean bottom, and reduce bycatch
- Conduct field work to determine whether fishing vessels can use oceanographic conditions as an indicator of species aggregations in order to avoid bycatch

❖ Understand ecological interactions within and between species

NEFSC has assembled comprehensive data sets to use in studying interactions among species on the Northeast Shelf LME. For example, our food habits data set includes more than 500,000 diet composition observations on more than 100 fish species, providing the nucleus for multispecies models for the shelf system. As part of our plan, the NEFSC will improve and further exploit this data set to:

- Develop and verify these models better to understand interactions among species
- Build on the limited data set for marine mammal and sea turtle diet composition to better understand ecological interactions for those species, and interactions between those species and commercial and recreational fisheries

The NEFSC is building a variety of models to understand and predict the effects of interspecies interactions in a management context. These include terms for human intervention in the system. Moving ahead, the NEFSC will:

- Further develop models at the more complex end of the spectrum, to be used for management strategy evaluation
- Further develop models of low to intermediate complexity, to be used to evaluate strategic and tactical management advice
- Proceed toward operational use of these models in the transition to ecosystem-based fishery management

Ecological interactions include diseases, which have affected managed species in the Northeast and are potentially devastating for small populations of threatened or endangered species. In order to better predict the likely effects of several presently poorly-understood diseases and outbreaks of these or other diseases, the NEFSC will:

- Investigate biogeographical variations in patterns of pathologies among marine organisms
- Develop an understanding of population-based differences in susceptibility to diseases

- Investigate how anthropogenic contaminants may cause shifts in phytoplankton community structure that could propagate throughout the food web
  - Continue investigation of metabolic pathways in diatoms and other occasionally pathogenic marine microorganisms to understanding factors that lead to the onset of toxicity
  - As necessary and appropriate, provide support for investigations of unusual mortality events among marine mammals and other protected species
- ❖ Forecast effects of environmental change on fish, invertebrate, marine mammal, sea turtle species, and human communities

The NEFSC strategy for studying climate and environmental change encompasses four major elements:

- Synthesize the present state of the ecosystem from analyses of previously collected data
- Understand the structure of physical properties and circulation above the continental shelf in response to forcing caused by climate change
- Determine the role of increased acidity in the ocean on structure and function of the ecosystem
- Develop and validate models predicting the future state of the ecosystem in response to observed and predicted changes in the climate

The goal of this research is to understand the present state of the Northeast Shelf LME and predict the future state in order to provide scientific information that helps sustain a healthy and diverse ecosystem, recover and conserve protected species, and support a healthy fishing economy. Extensive existing data bases for the Northeast LME allow progress on all four elements. The NEFSC will:

- Develop methods to predict changes in fish populations that may become permanent in response to climate change and affect the region's economic and social structure
  - Develop methods for integrating long-term climate forecasts into our ecosystem forecasts
  - Develop indicators of coastal community vulnerability and resilience in response to climate change
  - Characterize of the impact of ocean acidification on genetically diverse populations and marine ecosystems within the Northeast LME
- ❖ Conduct research on bioextraction as a means of removing excess nutrients from eutrophied waters

Agricultural runoff and the discharge of wastes results in the accumulation of undesirable concentrations of nitrogen, phosphorous, and other materials in inshore marine waters that can be mitigated by filter feeding organisms such as mussels. The NEFSC will continue its effort to evaluate this technique through small scale pilot projects at a variety of sites.

**Research Theme 3:** Describe and assess the role of habitats in ensuring healthy marine ecosystems; healthy populations of fish, invertebrates, marine mammals, and sea turtles; and resilient coastal communities and economies

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The NOAA Fisheries Service's Habitat Assessment Improvement Plan provides a framework and guidance for assessing habitats in order to improve stock assessment. The National Fish Habitat Action Plan provides a framework for relating the condition of fish habitat to coastal and inland human activities. The NEFSC now conducts research to understand the role pelagic and benthic habitat plays in the health and sustainability of fish, invertebrate and marine mammal populations within the Northeast Shelf LME, and the relationship of these to fisheries, economies and communities. For diadromous fish, we work to understand how the marine environment connects to the freshwater environment that is equally critical for these animals.

### Research Foci for Research Theme 3

- ❖ Assess and evaluate the importance of specific habitat types for populations of fish, invertebrate, turtle, marine mammal, and seabirds<sup>1</sup>

The NEFSC intends to continue habitat-related research providing data for improving stock assessments, constructing IEAs, informing coastal planning, and supporting climate change research. Over the next five years, the NEFSC will:

- Provide habitat assessments as required by the Magnuson-Stevens Act, the agency, and researchers
  - Continue development of habitat suitability models based partially on empirical data from the laboratory and field to predict of fish distributions (pelagic and benthic) in near-real time at sea
  - Participate in carrying out the National Fish Habitat Action Plan, which is characterizing inland, coastal and marine habitats in relation to human disturbances
- ❖ Evaluate and forecast impacts of human activities including fishing, on habitats of fish, invertebrates, marine mammals, and sea turtles

Human populations and activities are increasing along the coastal margin from Maine to North Carolina, already among the nation's most heavily populated areas. Managers need information about how these human activities affect fish, invertebrate, turtle, and marine mammal species in

<sup>1</sup> NMFS does not have responsibility for seabird assessments per se, but does have responsibility for assessing and mitigating bycatch of seabirds. Therefore NEFSC gathers seabird bycatch data via its fisheries observer programs and analyzes those data to estimate bycatch of seabirds and identify opportunities for mitigation.

order to mitigate those effects as necessary. The NEFSC will work to understand and forecast these impacts in a way useful to managers by:

- Further evaluating the effects of bottom-tending fishing gear on benthic habitats and the cumulative impacts of management alternatives to minimize those effects
- Conducting acoustic surveys of the seafloor to identify particularly vulnerable benthic habitats
- Further developing modeling techniques to characterize habitat vulnerability or sensitivity to natural and human disturbances
- Identifying risks posed to protected species by some fishing gears
- Understanding the ecosystem goods and services provided by damaged, restored, and alternative habitats
- Improving the spatial and temporal resolution of information on the abundance, distribution, and behavior of managed and protected species in order to reduce bycatch

Of increasing concern are Interactions between managed species and human activities other than fishing such offshore energy projects, Department of Defense activities, dredging, introduction of contaminants, and coastal infrastructure planning for non-fisheries development. Understanding the ecological footprint and the cumulative impacts of these activities on managed species is an important and very challenging topic of research.

Other types of anthropogenic activities are expected to increase potential release of contaminants into the ocean. The impacts of each type of activity must be evaluated in the context of our stewardship responsibilities and those of our partner federal agencies, so that both activity-specific and cumulative effects are understood and analyzed accurately.

The NEFSC will continue to assist those who plan for and evaluate these activities by:

- Sampling and analyzing habitat and organisms after oil spills or release of other contaminants, to help quantify the levels of exposure and consequent toxic effects for damage assessment
- Understanding the short- and long-term effects of an increasingly noisy ocean environment on marine mammals and other species
- Correlating the diversity and magnitude of anthropogenic activities with status of fish stocks and fishing mortality, to provide insight into cumulative effects on fisheries in the Northeast
- Conducting experiments using multiple environmental variables to evaluate cumulative effects of disturbances on species reproduction, behavior, and other physiological processes

❖ Provide information and analyses to support coastal planning

The NEFSC is evaluating renewable energy lease areas, responding to Requests for Interest released by the Bureau of Ocean Energy Management (BOEM) for potential wind farms sites from Maine to Virginia. We have developed an extensive catalog of physiographic, oceanographic, ecological, protected species, and fishery-related (both commercial and recreational) information for this purpose. Maps of other human uses including shipping lanes, telecommunication cables, sand extraction areas, and ocean dumping locations have been included.

NEFSC has provided specialized data layers to a number of state and local agencies. Data layers to represent pollution impacts, changes in nearshore and coastal habitats, hydrocarbon lease sites, past exploration data, and social and economic data are in preparation. Other data layers represent impacts of human activities include locations of incidental catches for mammals, turtles, and seabirds. In addition to mapping data to facilitate analyzing tradeoffs, NEFSC social scientists are researching governance arrangements and practices in an effort to facilitate more effective discussion of tradeoffs, and ease potential conflict, through participatory decision-making processes.

To further this capacity, NEFSC scientists will:

- Develop designed experiments that take advantage of existing contrasts between managed and non-managed areas to evaluate the impacts of management actions on ecosystem components and processes Map vulnerabilities and cumulative impacts of multiple stressors on the Northeast Shelf LME
- Continue to work with other bodies in the region on strategies for planning ocean use

***Research Theme 4: Understand the anthropogenic and ecological interactions of aquaculture on the continental shelf to ensure a safe and healthy supply of food***

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NOAA's Aquaculture Policy is intended to develop sustainable marine aquaculture within the context of our multiple stewardship missions and broader social and economic goals. Meeting this objective requires integration of environmental, social, and economic considerations in management decisions concerning aquaculture.

**Research Foci for Research Theme 4**

- ❖ Apply the contemporary tools of biotechnology and the biomedical field to applied research on the health of aquacultured organisms and their interactions with the environments in which they are cultured

Continuing research at NEFSC addresses physiological, biochemical, and DNA-based processes in cultured shellfishes, borrowing heavily from biomedical techniques. These include molecular studies on isolated cells, often using flow cytometry for the determination of mechanisms of environmental adaptation, metabolism, disease resistance, and reproduction. Over the next five years, these Investigations will further to address how this technology can be used in the health management of bivalve mollusks and other marine organisms.

- ❖ Conduct research on developing aquacultural methods for marine mollusks and finfish

Over the next five years, we intend to continue our efforts to improve the efficiency of environmentally-friendly shellfish and finfish cultivation by:

- Refining genetic stocks
- Culturing pure monocellular algae feeds
- Investigating probiotic treatments that boost immune resistance in cultured animals
- Conduct research on the culture and grow-out potential of integrated multitrophic mariculture: the simultaneous cultivation of multiple aquatic species from the use of byproducts of one species as inputs of another

### ***Research infrastructure and staffing***

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A wide range of technical, administrative, and support services and products are essential if the NEFSC is to function.

Critical to our mission are tasks, services, and infrastructure to collect and deliver data and samples, conduct business processes, ensure safe and appropriate working conditions, operate and maintain research platforms and equipment, communicate our activities and findings, and develop young talent for the future. Our historical accomplishments have relied on solid technical and support expertise, and we will continue to develop a multifaceted, highly functional technical workforce.

This section briefly describes our tools, facilities, and staffing, and summarizes what's required to support our strategic plan.

#### ❖ ***Manage, control & deliver data***

The NEFSC has extensive, complex data management responsibilities that support every research and management activity in the Center. Data (including biological samples) and data products must be high quality, accessible, and released in a timely manner consistent with applicable laws and policies. We require the capacity to archive, compile, process, interrelate, model, and analyze numerous independent data types totaling millions of records. Further, we must maintain and expand the documentation of metadata and other data management requirements. All this requires thoroughly modernized connectivity within NEFSC and with those who regularly interact with us.

#### ❖ ***Invest in information technology***

Information technology is an integral part of any monitoring program. Within the region, demands for new and more rapid data reporting and analysis have escalated with the advent of fishery annual catch limits and catch share management. Data integration is essential to the future and requires strong fundamental linkages among critical regional data sets, expansion and modernization of fishery- dependent data collection systems, migration to electronic data capture, and substantial upgrades to aging IT infrastructure.

At the same time, we must respond to increasing national mandates for IT security requirements or infrastructure improvements. Successful maintenance and enhancements of data collection programs will require significant increases in IT capacity.

Information Technology also plays an essential role in communicating our activities both internally and externally. The ongoing shifts toward digital and mobile connectivity, data visualizations, and interactive data deliver have blown through decades-old models for delivering public communications. To be effective and responsive this arena, we need to greatly increase our capabilities.

Finally, to ensure the safety and security of our data, our physical assets, and our people, IT infrastructure, capacity and innovation are essential. We will continue to make investments in this area, and to evaluate appropriate technologies and other resources.

❖ **Optimize our physical assets**

Buildings with office, laboratory, and library facilities and aquaria with environmentally and chemically controlled sea-water systems are necessary to achieve our research goals. The NEFSC maintains several facilities which are required to support research. NEFSC will seek funding to ensure our facilities meet the evolving needs of the research program and our staff.

The NEFSC owns and operates a fleet of small boats necessary for nearshore research activities. We also rely on both NOAA and chartered commercial vessels and aircraft to complete field work. To optimize use of NOAA ships and aircraft, we work closely with NOAA's Office of Marine and Aviation Operations and other NOAA line offices. For charter ships, we work with academia and the commercial fishing fleet.

We will continue to develop autonomous underwater vehicles and unmanned aerial vehicle to bring efficiency into various surveys and to increase capabilities for monitoring.

❖ **Manage business processes**

Business processes include finance, procurement, documentation, safety, security, and attending to human capital. These are the ongoing tasks that propel every organization forward. As NOAA increasingly centralizes these functions, requirements for training, reporting, documentation, and archiving are proliferating. We will investigate ways to make these tasks as easy as possible for the middle and upper managers who must conform to requirements. Means include an increasing use of digital and automated reporting and pursuing greater local authority for procurements and HR functions.

❖ **Attract, build, and support talent**

In 2006, amendments to the Magnuson-Stevens Fishery Act mandated a study on the supply of and demand for workers with post-baccalaureate degrees who can conduct high quality scientific research in fisheries stock assessment and related fields. The study found that the market for these scientists is expanding, and that the supply is severely limited. Causes include too few faculty and graduate students in the discipline.

Our educational related activities are to promote and advance:

- The quality of education and training for fisheries and fisheries-related students and research scientists
- Exchange of information, techniques, and materials among educators, and educational institutions
- Improved communication among fishery educators, employers, fisheries specialists, students, and the public
- Training and retention of existing NEFSC employees

The Center's strategy focuses on promoting environmental literacy and recruiting and training the next generation of people who will work in related marine and environmental fields. The Center has for many years had a strong equal opportunity, diversity, and inclusion emphasis in its programs, ensuring that students from all segments of society have opportunities to be introduced to fisheries and environmental research in the critical undergraduate years.

Undergraduate students are served throughout the year in small numbers. Paid summer intern programs are more formal, and spread interested students throughout our laboratories. We also manage a small but high-quality undergraduate intern program that involves all of the major research institutions in the village of Woods Hole.

NEFSC scientific staff partner with faculty and researchers in higher education institutions on teaching and curriculum innovation in fisheries related disciplines. For example, we are the primary partner in the NOAA Living Marine Resource Cooperative Science Center at the University of Maryland Eastern Shore Professional Science Master's Degree Program in Quantitative Fisheries and Resource Economics. NEFSC staff are adjunct professors in the program and at some other universities.

Unique to our center is the Woods Hole Science Aquarium, the nation's oldest marine aquarium. Approximately 100,000 visitors come to the aquarium annually. Its mission has education, research, and conservation components. It also houses our largest outreach projects for K-12 students. More than 200 high school students have passed through our summer intern program over the past 10 years. We have established formal school year programs with high schools on Cape Cod and Martha's Vineyard and an urban charter school in Dorchester, Massachusetts.

In addition to these efforts, the Center's laboratories offer volunteer opportunities throughout the year, including scientific berths aboard NOAA research vessels and support for the NOAA Teacher at Sea Program. We also provide outside scientists with biological and other samples for use in their research.