



**NOAA
FISHERIES**

Northeast Fisheries Science Center Science Plan

June 2013



Contents

Introduction	5
Research Themes and Foci	8
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 ...	8
Research Focus 1A. 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)	8
Research Focus 1B. 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)	11
Research Focus 1C. 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	12
Research Focus 1D. Conduct integrated ecosystem assessments and support ecosystem-based management within the Northeast LME to meet emerging management needs and mandates.....	14
Research Theme 2 Understand, forecast, and mitigate effects of environmental change (including climate change) on marine ecosystems, coastal communities, and economies	15
Research Focus 2A. Monitor and understand the effects of multiple and cumulative anthropogenic and natural changes on marine ecosystems and develop mitigation measures or tools where appropriate.....	15
Research Focus 2B. Understand ecological interactions within and between species.....	17
Research Focus 2C. Forecast effects of environmental change on fish, invertebrate, marine mammal, and sea turtle species, and on human communities.....	19
Research Focus 2D. Conduct research on bioextraction as a means of removing excess nutrients from eutrophied waters	20

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	20
Research Focus 3A. Assess and evaluate the importance of specific habitat types for fish, invertebrate, sea turtle, seabird, and marine mammal populations	20
Research Focus 3B. Evaluate and forecast impacts of human activities including fishing on habitats of fish, invertebrates, marine mammals, and sea turtles	21
Research Focus 3C. Provide information and analyses to support marine coastal planning.....	23
Research Theme 4: Understand the anthropogenic and ecological interactions of aquaculture on the continental shelf to ensure a safe and healthy supply of food	24
Research Focus 4A. 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.....	24
Research Focus 4B. Conduct research on developing aquacultural methods for marine mollusks and finfish	24
Science Support, Infrastructure, and Staffing	25
Manage, control and deliver data	26
Invest in information technology	26
Optimize our physical assets	27
Manage business processes	28
Attract, build, and support talent	28
Appendix 1 The Role of the Northeast Fisheries Science Center	30
Appendix 2 The NEFSC Science Plan and National Priorities for Ocean Research	33
Appendix 3 NEFSC Science Plan Implementation Process	35

The Northeast Continental Shelf Large Marine Ecosystem (LME), comprises 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.

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Bigelow* is one
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mary research
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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 of Northeast Continental Shelf Large Marine Ecosystem (LME), sustainable aquaculture and fisheries, and a better understanding of human influence on the ocean environment.

The Northeast Continental Shelf Large Marine Ecosystem (LME), comprises 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. (See Appendix 1 for more on the NEFSC's role in the region.)

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. (See Appendix 2 for more on our strategic plan and national priorities for ocean research.)

To do so, the plan relies on preserving our core capabilities and on building a broad-based science program, and engaging in extensive collaboration with external research partners and fishermen. This allows us to better support multi-level management of ocean use, to respond to legislative and treaty mandates, and to leverage assets with multiple research partners in the region.

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 collection for 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. We also support the broader NOAA Next Generation Strategic Plan, and our approach is consistent with that adopted by NOAA in crafting the larger agency plan.

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 (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, forecast, and mitigate 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.

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 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. The plan is implemented through an annual process that fits project for the year into the plan, our mandates, our stakeholder priorities, and our resources (Appendix 3, Figure A3.1.) Successful implementation occurs when all staff are engaged in priority activities that are properly resourced to meet expectations for results.

Table 1. Summary of 13 major research foci for the NEFSC grouped into four themes
Theme 1: Monitor, value, and assess fish, invertebrate, and marine mammal populations, fisheries, marine ecosystems, and the natural and human communities associated with them
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
Theme 2: Understand, forecast, and mitigate effects of environmental change (including climate change) on marine ecosystems, coastal communities, and economies
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 on human communities
Conduct research on bioextraction as a means of removing excess nutrients from eutrophied waters
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
Assess and evaluate the importance of specific habitat types for fish, invertebrate, sea 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
Theme 4: Understand the anthropogenic, ecological, and biological factors affecting development of sustainable marine aquaculture on the Northeast continental shelf
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

Research Themes and Foci

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

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.

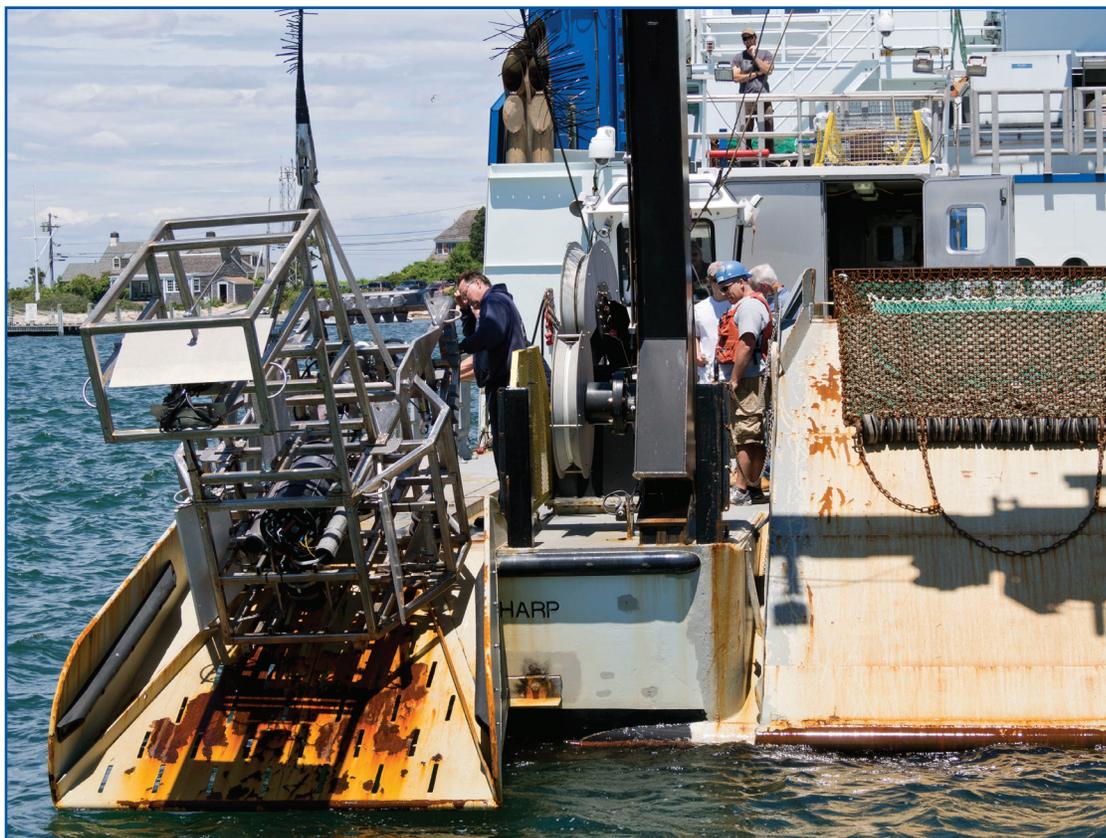
The first two research foci within this theme are our 'core' activities, representing work the NEFSC will continue under the most restrictive budget scenarios. The final two foci in this theme address enhancements to our core work, moving us toward integrated ecosystem-based products. Our ability to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

Research Focus 1A. 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 data are used not only by our scientists but also by a variety of researchers from outside the agency.

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 also 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 and video surveys for high-value species such as sea scallops, and for benthic habitat
- Acoustic/trawl surveys for pelagic fishery resources and other pelagic organisms
- Plankton surveys that collect data on changes at the base of the food web in an ecosystem context
- Coordinated processing of biological samples taken from specimens and used to estimate age, predation, and reproductive characteristics of harvested fish stocks
- Animal tracking using telemetry and passive acoustics



The Habcam (far left) ready for deployment along with a standard dredge for the sea scallop resource survey.

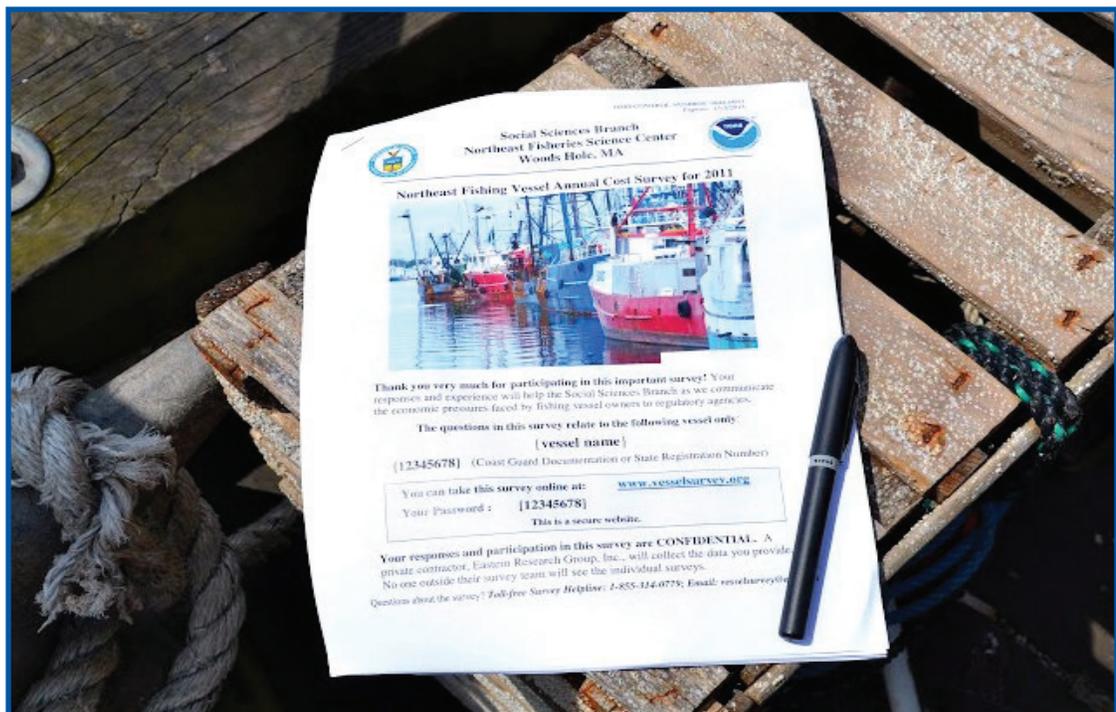
- Fishery observation and monitoring through the Northeast Fishery Observer Program, which collects biological samples, as well as landings, bycatch, gear, and fishing practice information on commercial vessels during fishing trips
- Surveys, oral histories, ethnological interviews, and focus groups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

We are evaluating and advancing these core monitoring activities and researching new technologies 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 intends to:

- Strengthen fundamental linkages among critical regional data sets to improve the efficiency of analytic procedures, especially those collected and maintained by NOAA
- 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 our IT infrastructure to improve data management and delivery to improve usefulness of these data for a variety of applications, including visualization and interactive applications

Social scientists at the NEFSC have revitalized efforts to gather social and economic information directly from vessels owners, skippers, and crew using mail surveys and face-to-face interviews



Research Focus 1B. 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)

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.

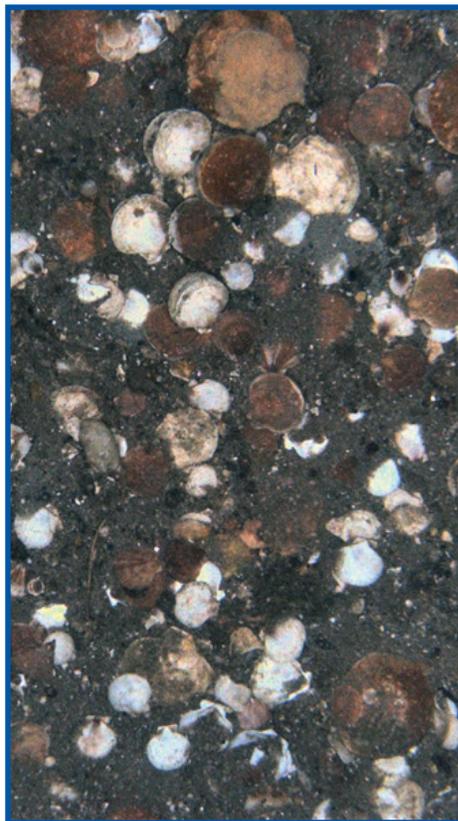
These assessments include evaluations of impacts of human activities on both protected and non-protected species. They are considered by resource managers in making decisions about recovering protected species, and by NMFS when completing required NEPA, ESA, and MMPA evaluations and determinations.

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 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.



HabCam image of sea scallops on the ocean bottom in the Great South Channel southeast of Cape Cod.

Yellowtail flounder, a challenging fish to assess owing to its current low numbers and transboundary distribution



Research Focus 1C. 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

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

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 incorporating 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 and sea turtle abundance trends, foraging habitat, fine scale distribution, and behavioral responses of marine mammals to stressors

- Strive to elevate marine mammal assessment quality to approach or 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
- Make advances in automatic processing of digital images and other samples to improve throughput
- Evaluate and improve, as appropriate, our ability to use acoustic methods to support stock assessment and ecosystem monitoring
- Evaluate the potential for new technologies -- including animal telemetry systems, passive acoustic arrays, autonomous underwater vehicles, and gliders-- to serve as research or monitoring tools. Implement technological advances as appropriate.

The NEFSC Integrated Ecosystem Monitoring Initiative lays the groundwork for a new sampling strategy to support ecosystem-level analyses, through which we intend to:

- Evaluate spatial and temporal domains for sampling
- Consider the need for population, multispecies, and ecosystem models



Loggerhead turtle returned to the sea with freshly applied satellite tag placed in a study that tracks turtle movements over time.

- Develop ecosystem indicators that will help determine which, and at what scale, observations should to be made
- Enhance and expand ongoing social and economic surveys of fishers and fishing communities

Figure 1. 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



Research Focus 1D. 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. 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 1).

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 provides a counterpart to single-species stock assessments for ecosystem-based fishery management.

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 use, the NEFSC intends to:

- Develop an IEA for the NE Continental Shelf directly and through partnerships
- 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 research that allows 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

Research Focus 2A. Monitor and understand the effects of multiple and cumulative anthropogenic and natural changes on marine ecosystems and develop mitigation measures or tools where appropriate

The structure of the marine environment on the continental shelf off the northeastern United States has changed significantly in recent decades, affecting the oceanography of the continental shelf and the abundance and distribution of fish, invertebrates, marine mammals, sea turtles, and seabirds. There are also implications for human communities that depend on marine resources. The NEFSC must continue to monitor and understand these changes in order to advise management bodies striving to mitigate their ecological, social, and economic impacts.

To better inform management, the NEFSC intends to:

- Identify key threats to the ecosystem services (Appendix 2, Figure A2.2) in the region



A grilse Atlantic salmon from the Gulf of Maine. NEFSC researchers have shown that southerly predator species have ridden warming waters into the Gulf of Maine, increasing risks to these endangered fish.

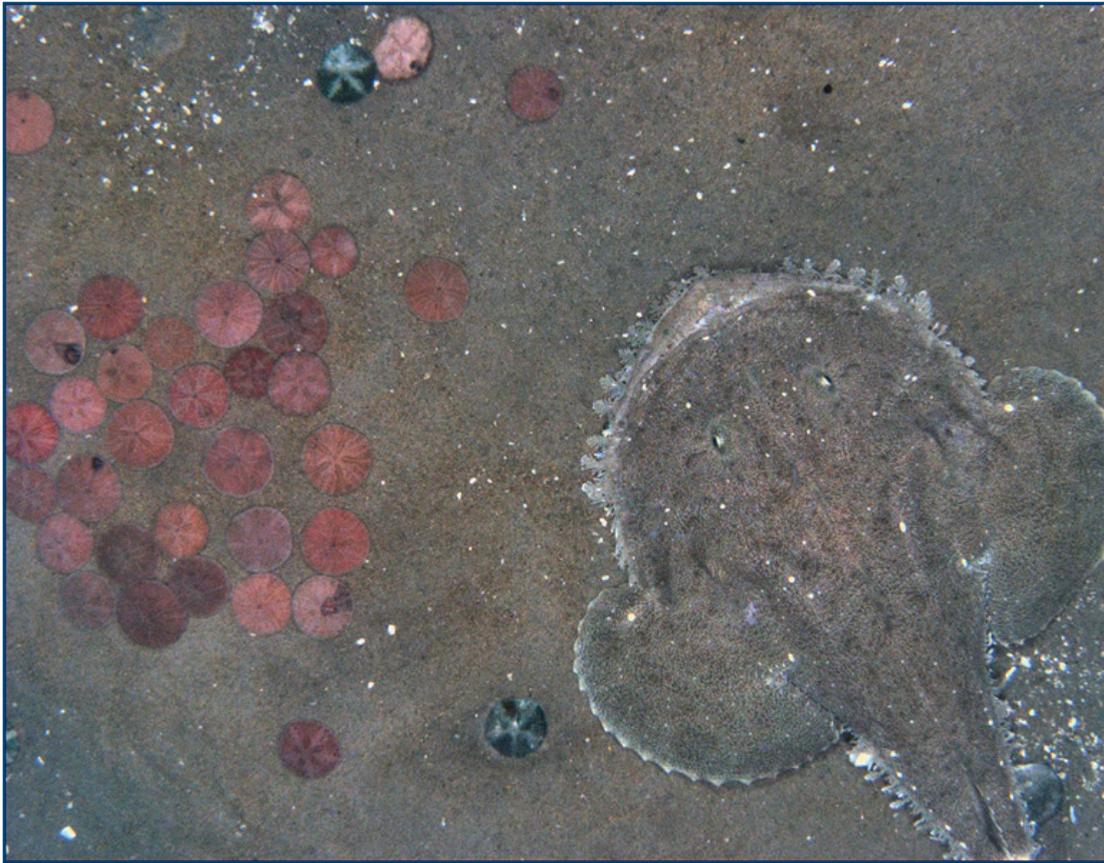
- Examine trends in climate indicators and model these effects in the region at the population and community (human and natural) levels
- Develop models that allow us to better evaluate the consequences of multiple impacts, evaluate potential mitigations, and assess cumulative effects
- Evaluate fishery monitoring strategies relative to science, management, and compliance, implementing improvements as appropriate
- Develop fishing gear and practices that are more selective for target species can lessen undesired effects of fishing.

Through cooperative research with external researchers and fishing professionals the NEFSC intends to continue to:

- Participate in development and testing of gear designs and improvements that reduce disturbance or damage to ocean bottom, and reduce bycatch
- Conduct research to determine whether fishing vessels can use oceanographic conditions as indicators to reduce bycatch

Catch made on the F/V *Westport* in a 2011 sea scallop research set-aside (RSA) project that tested dredge designs that would reduce flatfish bycatch. Research set-asides are cooperative research programs unique to the Northeast. Projects are funded through sale of a portion of the annual commercial fishery quota.





A goosefish and sand dollars share bottom habitat, just south of Block Island.

Research Focus 2B. 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 multi-species models for the shelf system.

As part of our plan, the NEFSC will improve and further exploit these data sets to:

- Develop and verify multispecies models to better 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.

Healthy harbor seals on a sandy stretch of beach near Chatham Harbor, Mass. Harbor seals have experienced unusual mortality events in recent years, and stranded animals are monitored for signs of disease or other health concerns.



Moving ahead, the NEFSC intends to:

- Further develop models at the more complex end of the spectrum, to be used evaluate interactions
- 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 can be 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 intends to:

- Investigate biogeographic variation in patterns of pathologies among marine organisms
- Better understand 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 understand factors in toxicity onset

- As necessary and appropriate, provide support for investigations of unusual mortality events among marine mammals and other protected species

Research Focus 2C. Forecast effects of environmental change on fish, invertebrate, marine mammal, and sea turtle species, and on human communities

The NEFSC strategy for studying climate and environmental change has three major elements:

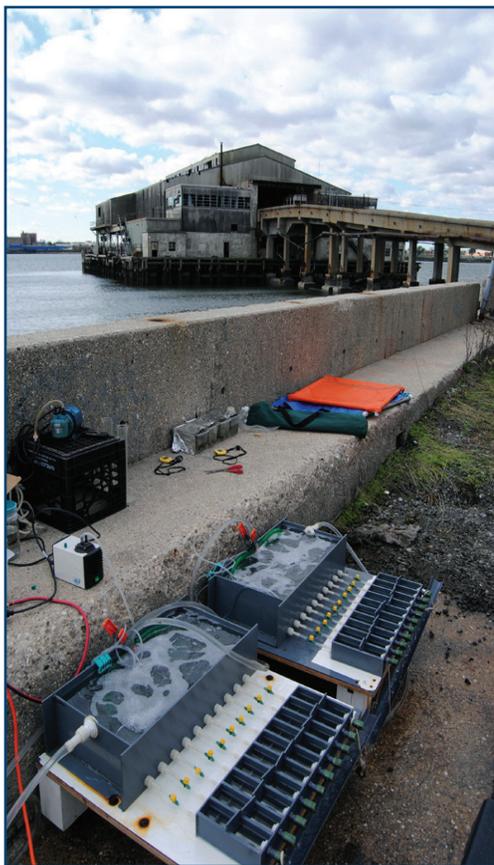
- Synthesizing the structure of physical properties and circulation above the continental shelf in response to forcing caused by climate change
- Determining the role of increased acidity in the ocean on structure and function of the ecosystem
- Developing and validating models predicting the future 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 its 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.



American oysters cultivated, harvested, shucked, and served by Perry Raso, owner of Matunuck Oyster Farm and oyster bar in Rhode Island. Oysters are among the seafood that could be threatened by warming waters and ocean acidification. Researchers at NEFSC labs at Sandy Hook N.J., and Milford, Conn. are working on quantifying these effects on fish, shellfish, and phytoplankton.

Apparatus to measure mussel filtration sits near an abandoned waste transfer station on the Bronx River near Hunts Point. NEFSC researchers tested the ability of ribbed mussel to filter pollutants in the river over two-years. Filtration rates were measured by pumping local water through the pictured apparatus. One surprising early result? The Bronx River was cleaner than expected.



The NEFSC will work toward:

- Developing 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
- Developing methods to integrate long-term climate forecasts into our ecosystem forecasts
- Developing indicators of coastal community vulnerability and resilience in response to climate change
- Conducting research that supports characterization ocean acidification effects on genetically diverse populations and marine ecosystems within the Northeast LME

Research Focus 2D. 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

The NOAA Fisheries Service's Habitat Assessment Improvement Plan provides a framework and guidance for assessing habitats in order to improve stock assessment, and 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 Focus 3A. Assess and evaluate the importance of specific habitat types for fish, invertebrate, sea turtle, seabird, and marine mammal populations

The NEFSC intends to continue habitat-related research providing data for improving stock as-

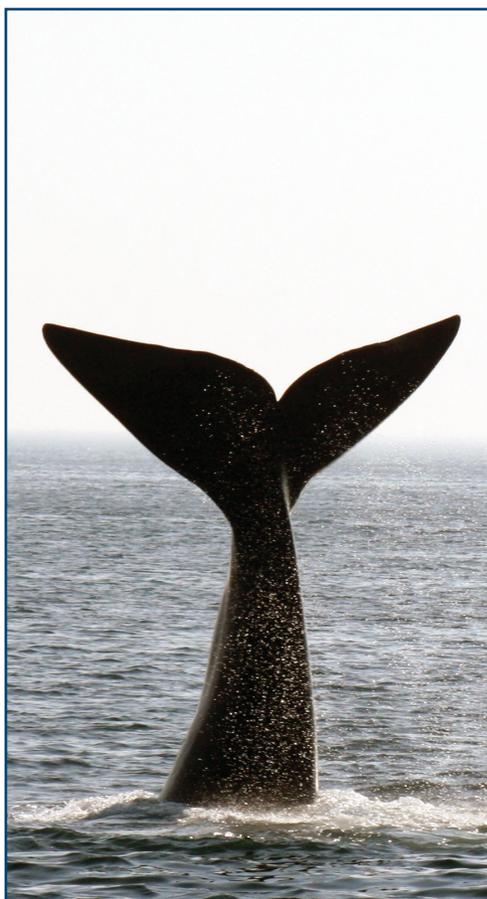
assessments, constructing IEAs, informing coastal planning, and supporting climate change research.

The NEFSC will work toward better habitat understanding, assessment, and linkage by:

- Conducting habitat assessments
- Continuing to develop habitat suitability models to predict of fish distributions (pelagic and benthic) in near-real time at sea
- Participating in activities under the National Fish Habitat Action Plan

Research Focus 3B. 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 order to mitigate those effects as necessary.



The North Atlantic right whale is among the rarest large whales in the world. Its range is predominantly nearshore. Vessel traffic, noise, and some kinds of fishing present hazards to these endangered animals. NEFSC researchers are working to help find ways to mitigate these risks by better understanding when, where, and how these animals are using their habitats.

The NEFSC intends to work toward understanding and forecasting these impacts 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
- Improving our understanding of the ecosystem goods and services provided by damaged, restored, and alternative habitats

Of increasing concern are interactions between managed species and human activities other than fishing such as offshore energy projects, Department of Defense activities, dredging, introduction of contaminants, and coastal infrastructure planning for non-fisheries develop-

ment. 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 intends to continue assisting those who plan and evaluate these activities by:

- Improving our understanding of 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 research using multiple environmental variables to evaluate cumulative effects of disturbances on species reproduction, behavior, and other physiological processes

NEFSC researchers are using passive acoustic devices like this one to listen for whales in heavily trafficked ocean areas off Massachusetts, that are also important feeding areas for endangered whales.





Normally invisible, wind wakes take shape in the clouds behind the Horns Rev wind farm west of Denmark. Plans for offshore energy projects off the US East Coast that would derive power from wind and tides have multiplied for locations off the US East Coast. NEFSC researchers are helping to ensure that risks to the marine environment and its wildlife are properly considered when selecting sites for development.

Research Focus 3C. Provide information and analyses to support marine 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 (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. We are preparing data layers to represent pollution impacts, changes in nearshore and coastal habitats, hydrocarbon lease sites, past exploration data, and social and economic data. Other data layers represent impacts of human activities including locations of incidental catches for mammals, turtles, and seabirds. In addition to mapping data to facilitate analysis of 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 intend to:

- Conduct research that contrasts managed and non-managed areas to evaluate the impacts of management actions on ecosystem components
- Contribute to ocean planning efforts with other NOAA line offices and organizations in the region

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

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 Focus 4A. 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

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. Under this science plan, these investigations will further address how this technology can be used in the health management of bivalve mollusks and other marine organisms.

Research Focus 4B. Conduct research on developing aquacultural methods for marine mollusks and finfish

We intend to continue our efforts to improve the efficiency of environmentally-friendly shellfish and finfish cultivation by:

- Refining genetic stocksulturing pure monocellular algae feeds
- Investigating probiotic treatments that boost immune resistance in cultured animals
- Conducting 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

Science Support, Infrastructure, and Staffing

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.



Life vest await visiitors to the NEFSC R/V Nauvoo at the James J Howard 50th anniversary open house at Sandy Hook, NJ

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 visualiza-

Second graders at the Fishing Cove elementary School in North Kingstown R.I., decorated 51 styrofoam cups. NEFSC oceanographer Jerry Perzioso took them along on an ecosystem monitoring research cruise, and deployed the cups in a mesh bag along with a water sampling array. The students got their shrunken cups back and learned about water pressure in the ocean.



tions, and interactive data delivery have blown through decades-old models for delivering public communications. To be effective and responsive in this arena, we need to acquire new capabilities and build on existing ones.

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.



NEFSC seal researcher Gordon Waring being interviewed at Barnstable Harbor by CBS News correspondent Seth Doane for a story on the burgeoning gray seal population around Cape Cod. NEFSC researchers are in constant demand by news outlets seeking expert interviews on a variety of marine science topics.



Low-tech drifters built by NOAA Teachers at Sea alumni and deployed by NEFSC sea turtle researchers during a 2012 tagging cruise. The drifters were released along with tagged turtles to study whether the turtles followed specific currents or wind-driven sources of food.

LuSeal, a harbor seal, at the NEFSC Woods Hole Science Aquarium. The aquarium is the nation's oldest public aquarium and is a year-round focal point for NEFSC outreach and education with K-12 students as well as the large number of summer visitors .



Woods Hole Science Aquarium high school interns have a busy schedule, and learn about a variety of marine-related careers. Working with the harbor seals, especially assisting with enrichment activities like this one, is a high point of the program for most.



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-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.



Spray over the bow of the NOAA R/V Delaware II on a gray day in the Northeast Atlantic Ocean.

Appendix 1

The Role of the Northeast Fisheries Science Center

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.

The first permanent federal marine fishery research laboratory, on the site of today's NEFSC headquarters in Woods Hole, Mass. in 1891. The Albatross I pictured left.



Together with the Woods Hole Laboratory, they account for the shape of today's NEFSC.

Our resource issues are complex. Many of the nation's overfished marine fishery stocks 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 up 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 and relies on 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, especially the NMFS Northeast Regional Office and the regional fishery management councils and commissions, 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, and the International Coun-



Close-up of the eyes of *Teuthowenia megalops*, the cockatoo squid, photographed by Michael Vecchione, an internationally known expert on the world's squids and director of the National Systematics Laboratory, located at the Smithsonian Institution and administered by the NEFSC.

Commercial fishing vessels on the historic New Bedford, Mass. waterfront. New Bedford has been the nation's top-grossing port for nearly 20 years.



cil 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 of Appendix 2 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.

Appendix 2

The NEFSC Science Plan and National Priorities for Ocean Research

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.

Figure A2.1 Key goods and services derived from the ocean
Ecosystem Services
Fisheries
Aquaculture
Energy Production
Regulating Services
Climate regulation
Filtration
Waster disposal
Supporting Services
Habitat provision
Primary production
Nutrient cycling
Cultural and Amenity Services
Tourism
Recreation
Lifeways

Ecosystem-based management provides an integrated framework for the sustainable delivery of ecosystem goods and services (Figure A2.1.) 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 A2.2.)

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 ser-

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

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 21st Century

A mixed North Atlantic trawl haul: fish, molluscs, starfish and rocks



Early calm morning on the Gulf of Maine.



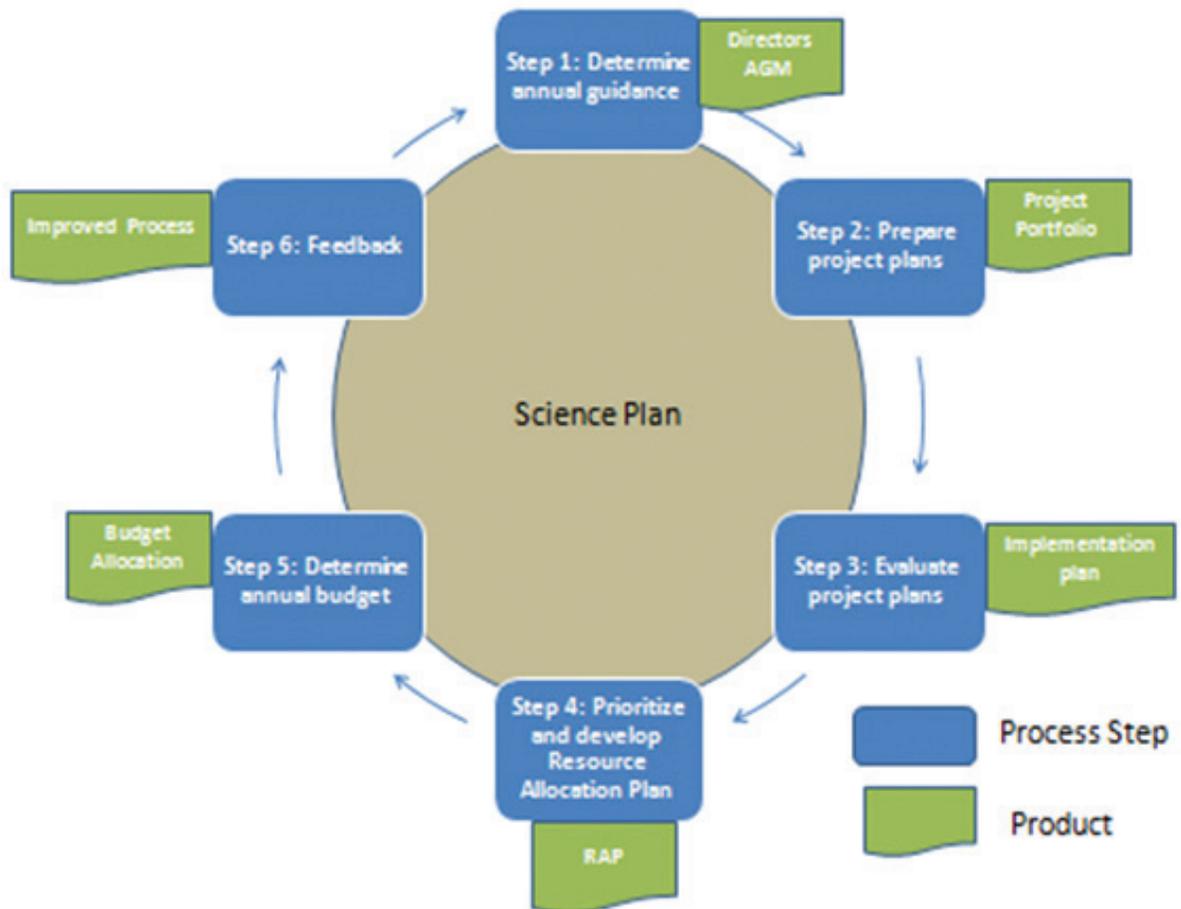
Figure A2.2 Factors Affecting viability of ocean ecosystem services

Overfishing
Food web alteration
Climate change
Biodiversity loss
Cultural diversity loss
Habitat loss
Habitat degradation
Impacts on threatened species
Loss of economic opportunity
Pollution

Appendix 3

NEFSC Science Plan Implementation Process

Figure A3.1. Process and Products





U.S. Secretary of Commerce
Cameron F. Kerry (acting)

**Administrator of National Oceanic and Atmospheric
Administration and Undersecretary of Commerce**
Kathryn D. Sullivan (acting)

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