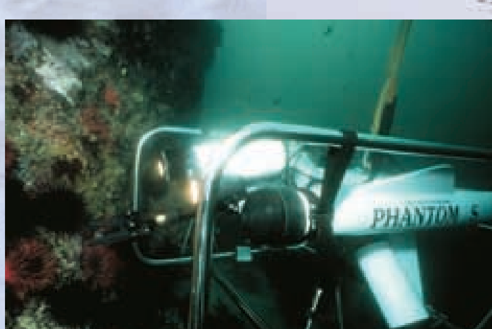
National Marine Fisheries Service

Habitat Assessment Improvement Plan

May 2010



U.S. DEPARTMENT OF COMMERCE

Marine Fisheries
Habitat Assessment Improvement Plan

Report of the National Marine Fisheries Service
Habitat Assessment Improvement Plan Team

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U.S. DEPARTMENT OF COMMERCE
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Cover images: Background - Palmer Seamount bathymetric map (NOAA, NOS). Photos (top to bottom) - swordspine rockfish resting in a sponge (SWFSC Fisheries Resources Division); juvenile fish in mangrove nursery habitat (Tom Minello, SEFSC); gray snappers on a Florida reef (Florida Keys National Marine Sanctuary); CTD and water sampling equipment (NOAA Climate Program Office); California salmon stream survey (SWFSC); NOAA Ship *John N. Cobb* working in Glacier Bay, Alaska (Commander John Bortniak, NOAA Corps); Phantom S2 ROV working underwater in the Gulf of the Farallons National Marine Sanctuary (OAR, National Undersea Research Program).

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Preface

A little more than a century ago, the ocean was considered by many to be capable of providing a boundless supply of seafood. Today, our views have changed radically. We have learned that it is very easy to overfish and that we must be cognizant of what we discharge into coastal waters. We also have learned that atmospheric emissions can have a profound impact on the chemistry of the oceans and affect climate regimes worldwide. We are now beginning to understand the connectedness of living things and their environment, and know that what happens to their habitats can affect their ability to survive and reproduce.

The science of understanding the relationship of living marine resources to their habitats is still in its infancy. Virtually any piece of research into this relationship opens up new and intriguing vistas, generating more questions than answers. As American society places more demands on coastal and offshore regions for food, energy, transportation, waste disposal, community development, and recreation, the burden on the Federal government to provide scientific information to support informed management decisions becomes more onerous.

Because of its mandated responsibility for promoting sustainability of marine fisheries resources, the National Marine Fisheries Service has a unique role in habitat science and assessment. This document, for the first time, defines that role and lays out a plan to integrate habitat science into everyday decision-making that affects the contribution of marine fisheries to the U.S. and world economies, as well as the state of marine ecosystems. Recognizing that we cannot afford to delay decisions until we have a perfect understanding of the relationship between fisheries and the habitats that support them, this document provides an incremental approach that allows factoring of scientific information into habitat assessments as more knowledge is gained. An incremental approach ensures that the best scientific information to support management decisions affecting habitats is available and continually improving.

Now that we finally have the ball in play, let's not drop it.

John Boreman
Director (retired)
NMFS, Office of Science and Technology
June 2009

Executive Summary

NOAA's National Marine Fisheries Service (NMFS) has a mandated responsibility to sustain marine fisheries and associated habitats. The Marine Fisheries Habitat Assessment Improvement Plan (HAIP) defines NMFS' unique role in pursuing habitat science and in developing habitat assessments to meet this mandate. Through this Plan, NMFS establishes the framework to coordinate its diverse habitat research, monitoring, and assessments and to guide the development of budget alternatives and increased support for habitat science.

The HAIP has been developed by a team of scientists from NMFS Headquarters Offices and Science Centers. This Plan represents input from a variety of NMFS staff engaged in habitat science, stock assessments, and resource management at the six Science Centers and Regional Offices, the Office of Science and Technology, the Office of Habitat Conservation, and science program managers at each Science Center. The scope of the HAIP is restricted to the 519 managed stocks and stock complexes within Fishery Management Plans, with particular focus on the 230 stocks in the Fish Stock Sustainability Index (FSSI). The conclusions and recommendations of the HAIP, however, can be applied more broadly to other managed and protected species.

The goals of the HAIP are to:

- Assist the National Oceanic and Atmospheric Administration (NOAA) in developing the habitat science necessary to meet the mandates of the Magnuson-Stevens Fishery Conservation and Management Reauthorization Act (MSRA) and the economic, social, and environmental needs of the nation;
- Improve our ability to identify essential fish habitat (EFH) and habitat areas of particular concern (HAPC);
- Provide information needed to assess impacts to EFH;
- Reduce habitat-related uncertainty in stock assessments;
- Facilitate a greater number of "Marine Fisheries Stock Assessment Improvement Plan" (SAIP)[1] Tier 3 stock assessments, including those that explicitly incorporate ecosystem considerations and spatial analyses;
- Contribute to assessments of ecosystem services (i.e. the things people need and care about that are provided by marine systems); and
- Contribute to ecosystem-based fishery management (EBFM), integrated ecosystem assessments (IEA's), and coastal and marine spatial planning (CMSP).

Habitat, or the place where species live, can be characterized and described by the physical, chemical, biological, and geological components of the ocean environment. Habitat science is the study of relationships among species and their environment. Habitat science has received relatively little programmatic support compared to that received for other major disciplines (e.g. stock assessment science), and yet habitat information is needed in almost every NOAA program. Habitat science is not synonymous with ecosystem science, but habitats form the structural matrix of ecosystems, and an understanding of geospatial associations of species and their habitats can be one of the first steps in producing IEA's. A habitat assessment is the process and the products associated with consolidating, analyzing, and reporting the best available information on habitat characteristics relative to the population dynamics of fishery species and other living marine resources. Indicators of the value and condition (or status) of habitat can be developed through a habitat assessment by understanding the relationships between habitat characteristics, the productivity of fishery species, and the type and magnitude of various impacts.

There is an incontrovertible need for NMFS to move forward in implementing the HAIP. The role of marine habitats in supporting fishery production and in providing other critical ecosystem services is poorly understood. There are increasing

[1]NMFS. 2001. Marine fisheries stock assessment improvement plan: Report of the National Marine Fisheries Service National Task Force for Improving Fish Stock Assessments. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-F/SPO-56, 69 p.

demands and impacts on marine habitats across many sectors of the U.S. economy. Climate change, for example, can have potentially large and far-reaching impacts on marine habitats. Lack of knowledge about the association of marine species and their habitats impedes effective fisheries and habitat management, protection, and restoration, and yet this information forms the basis for assessing impacts of human activities on ecosystem services in the context of CMSP. NMFS currently lacks a comprehensive habitat science program that is sufficiently funded to address these issues.

A number of uses for habitat assessments are highlighted in Section 3. EFH provisions in the MSRA form the cornerstone of NMFS' mandated habitat responsibilities, yet designation of EFH for many Federally managed stocks has been based on inadequate information and has been too broadly defined to provide for meaningful management measures. NMFS mandates also require adequate assessments for Federally managed stocks. Accurate assessments of the distribution and abundance of many of these stocks would benefit from improved information on their habitats. This report discusses these and other factors that define NMFS' habitat-related mandates as well as many independent reviews that recommend improved habitat science to support more effective marine resource management.

Recommendation:

- NMFS and NOAA should develop new budget and staffing initiatives to fund habitat science that is directly linked to NMFS mandates.

Habitat assessments can and should be used for habitat management, conservation, and restoration. Understanding the distribution, abundance, and functions of marine habitats also will assist in CMSP, particularly with effective siting, design, and monitoring of marine protected areas (MPA's). Further, understanding and predicting the effects of climate change and other anthropogenic impacts on ocean resources will require an increased emphasis on habitat science.

Habitat science also can inform stock assessments. Most stock assessments currently lack integration of habitat data, aside from depth and geographic stratification of fisheries-independent surveys. Uncertainty in species abundance may be reduced by considering how habitats affect:

- The design of fisheries-independent surveys and resultant estimates of stock size;
- Catchability coefficients;
- Vital rates, such as natural mortality, growth, and reproduction;
- Stock-recruit functions;
- Nursery functions; and
- The spatial and temporal scales of animal movements.

Most NMFS stock assessment biologists surveyed by the HAIP Team thought that habitat-specific stock assessments would require at least some modification of existing models, if not entirely new models. This conclusion varied based on the type of habitat data, the life history of the species studied, and the geographic region in which the scientist worked.

Recommendations:

- NMFS should develop criteria to prioritize stocks and geographic locations that would benefit from habitat assessments.
- NMFS habitat and stock assessment scientists should work together to initiate demonstration projects that incorporate habitat data into stock assessment models, perhaps focusing on well-studied species.

Habitat assessments require both collection and synthesis of multiple data types at a variety of temporal and spatial resolutions. In Section 4 we describe how research efforts to collect habitat data have been fragmented and limited, with our greatest success demonstrated by the physical characterization of habitats. A survey of NMFS scientists indicated that most habitat data presently are inadequate and occur at low spatial and temporal resolutions.

From the HAIP questionnaires, NMFS scientists, resource managers, and Science Center program managers identified the following as major obstacles to producing and using credible habitat assessments:

- Lack of habitat-specific abundances;
- Insufficient staff to collect, process, analyze, and model habitat data;
- Insufficient research on environmental effects;
- Insufficient research on multispecies effects; and
- Lack of habitat-specific biological information.

Resource managers also identified an inadequate number of staff to communicate habitat information to NMFS constituents as a major obstacle to producing and using habitat assessments.

Primary challenges to the effective management of habitat data are:

- The multiplicity of data types and the large volume of habitat imagery data;
- The lack of appropriate metadata and accessibility to research data; and
- The means to efficiently collect and process data and produce the required products.

Recommendations:

- NMFS should identify and prioritize data inadequacies for stocks and their respective habitats, as relevant to information gaps identified in the HAIP.

- NMFS should increase collection of habitat data on fishery-independent surveys and develop a plan for better utilizing new technologies (e.g. multibeam sonars) aboard the expanding NOAA fleet of Fishery Survey Vessels (FSV's).

In Section 5, the HAIP Team defines three Tiers of Excellence for Habitat Assessments, which can be summarized as:

Tier 1 – Assess habitat associations for all life stages of FSSI stocks using existing data.

Tier 2 – Upgrade habitat assessments to a minimally acceptable level for all FSSI stocks and life stages, which will require new or expanded data collection and research initiatives. This effort includes the production of habitat maps; determination of habitat-specific biomass or abundance; consideration of temporal and spatial variability in habitat use; and development of habitat theory and proxies to apply to data-poor stocks.

Tier 3 – Determine habitat-specific vital rates by life stage for all FSSI stocks to quantify relationships between habitats and fishery production. This effort explicitly incorporates habitat and ecosystem considerations into stock assessments; develops habitat sensitivity and recovery indices to improve risk assessments and plans for protection and restoration; and develops baselines for IEA's.

The tiers require increasing levels of resolution in assessment data and an increased understanding of the functioning of habitats for fishery species. Progress through the tiers is not necessarily sequential and will depend on the research needs, staff expertise, and infrastructure available at each Science Center.

Inadequate numbers of technical and scientific staff have been identified as a major obstacle to credible habitat assessments. Section 5 includes the national summary of staffing requirements, as identified by program man-

Recommendations:

- NMFS habitat scientists should engage partners within and outside of NOAA to exchange information about programs and capabilities. Habitat data collection and management efforts should be coordinated, and data integration applications should be upgraded to improve accessibility and synthesis.

- NMFS should convene regional and national workshops to develop strategies to integrate habitat science and assessments, stock assessments, and IEA's.

- NMFS should establish a habitat assessment fellowship program and provide funds to graduate students and post-doctoral associates of specific subdisciplines that would advance habitat modeling, evaluation, and assessment efforts.

agers at the Science Centers, that are needed to meet the three Tiers of Excellence for Habitat Assessments (see Appendix 7 for region-by-region requirements). About 5% of total NMFS staff are currently working on habitat-related activities at the Science Centers, and an average of 33% of those staff are contractors and students supported with transient, non NMFS funds. This is a major concern given the ever-increasing demands on NMFS to effectively conserve, protect, and manage living marine resources. Full implementation of the HAIP will require a 250% increase in staff over the current habitat-related staff, and a substantial increase in funds for program operations, tools, technology, and infrastructure.

To demonstrate effectiveness of investments, NMFS must monitor program accomplishments through performance measures. In Section 6, the HAIP outlines characteristics of potential performance measures that will reflect progress toward meeting the three Tiers of Excellence for Habitat Assessments. Topic areas for evaluating performance include biological and geospatial information, habitat condition indices, and habitat assessments.

The HAIP is unique because it is the first nationally coordinated plan to focus on the marine fisheries aspects of habitat science. However, in order to make substantial progress toward collecting, managing, and synthesizing the data needed to improve our habitat assessments, it is essential that NMFS continue to foster partnerships and cooperative research programs with other groups. Section 7 and Appendix 6 of the HAIP highlight a number of important NMFS partners, including other NOAA line offices, non NOAA Federal agencies, state agencies, private foundations, universities, environmental groups, fishing organizations, and others with an interest in collecting and using similar types of habitat data, albeit often for different purposes. Partners can contribute research and development, field sites and equipment, raw data and synthesized products, scientific and technical expertise and training, and data management and archiving. All partners will benefit from, as well as contribute to, the success of the HAIP.

Recommendation:

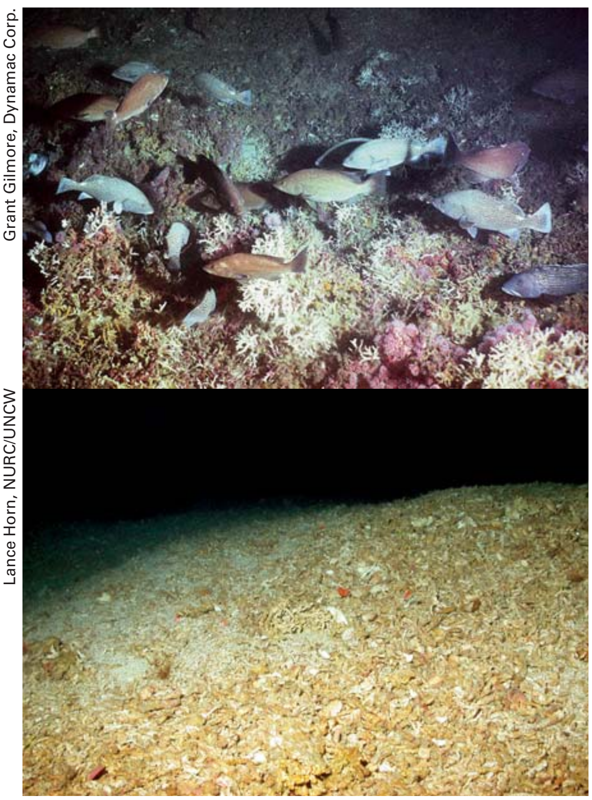
- NMFS should unite with other NOAA line offices to develop a NOAA-wide strategic plan for habitat science and assessments in support of the nation's ocean policy priorities for EBFM, CMSP, and the use of IEA's.

Section 1: Introduction

At a Glance

- The Marine Fisheries Habitat Assessment Improvement Plan (HAIP) defines the National Marine Fisheries Service's (NMFS') unique role in pursuing habitat science and in developing habitat assessments to meet its mandated responsibility to sustain marine fisheries and associated habitats.
- Through the HAIP, NMFS establishes the framework to coordinate its diverse habitat research, monitoring, and assessments and to guide the development of budget alternatives and increased support for habitat science.
- The scope of the HAIP is restricted to managed stocks and stock complexes within fishery management plans, with particular focus on the stocks in the Fish Stock Sustainability Index.
- The conclusions and recommendations of the HAIP, however, can be applied more broadly to other managed and protected species.

The Marine Fisheries Habitat Assessment Improvement Plan (HAIP) defines the National Marine Fisheries Service's (NMFS) unique role in pursuing habitat science and in developing habitat assessments to meet its mandated responsibility to sustain marine fisheries and associated habitats. The HAIP presents an evaluation of NMFS' current habitat science capabilities and unmet needs. In this Plan, deficiencies in NMFS' ability to provide accurate and defensible assessments of marine fisheries habitats are identified, and recommendations are provided for addressing these deficiencies. Through this Plan, NMFS also establishes the framework to coordinate its diverse habitat research, monitoring, and assessments and to guide the development of budget alternatives and increased support for habitat science.



Grant Gilmore, Dynamac Corp.

Lance Horn, NURC/UNCW

Comparison of healthy and impacted habitats. Top photo shows commercial groupers on healthy *Oculina* deep-sea coral habitat off the east coast of Florida. Bottom photo shows a similar *Oculina* habitat that has been impacted by trawling.

The goals of the HAIP are to:

- Assist the National Oceanic and Atmospheric Administration (NOAA) in developing the habitat science necessary to meet the mandates of the Magnuson-Stevens Fishery Conservation and Management Reauthorization Act (MSRA) and the economic, social, and environmental needs of the nation;
- Improve our ability to identify essential fish habitat (EFH) and habitat areas of particular concern (HAPC);
- Provide information needed to assess impacts to EFH;
- Reduce habitat-related uncertainty in stock assessments;
- Facilitate a greater number of "Marine Fisheries Stock Assessment Improvement Plan" (SAIP) Tier 3 stock assessments (NMFS, 2001), including those that explicitly incorporate ecosystem considerations and spatial analyses;
- Contribute to assessments of ecosystem services (i.e. the things people need and care about that are provided by marine systems); and

Habitats provide a wide variety of important ecosystem services. In addition to protecting coastal areas from erosion and storm surge, mangrove roots provide important habitat for a number of commercially important fishery species.

- Contribute to ecosystem-based fishery management (EBFM), integrated ecosystem assessments (IEA's), and coastal and marine spatial planning (CMSP).

Loss of marine habitats can lead to decreased fishery production (Hutton et al., 1956; Zimmerman and Nance, 2001). However, the significance of marine habitats in providing the essential ecosystem services that support the social and economic well-being of the nation is poorly understood. This lack of knowledge is of growing concern, especially because our increasing demands for energy, shipping, seafood, and development exert untold impacts on our nation's marine and coastal habitats. Added to these stresses are the potentially large impacts to fishery habitats that are related to climate change, including increased ocean temperatures, sea level rise, ocean acidification, changes in freshwater flow, and alterations to weather patterns. Furthermore, conflicting demands on limited marine resources challenge our ability to balance fisheries quotas and habitat conservation with industrial growth.

We urgently need to improve our management of ocean resources. Our ability to manage these resources from an ecosystem perspective requires an understanding of the linkage between marine habitats and living marine resources (LMR). The lack of knowledge about the significance of marine habitats to LMR's currently prevents managers from incorporating impacts of habitat change into stock assessments and management plans, despite considerable demand for this information from fishery managers and many other stakeholders. For this reason, the U.S. Commission on Ocean Policy (COP, 2004) and other independent review bodies have called for NOAA to implement a coordinated national habitat science program to better understand the relationships between managed fishery species and their habitats.

Ensuring the sustainability of our fisheries, LMR's, and ecosystems is a major national goal. Commercial and recreational fishing contribute billions of dollars to the U.S. economy each year. In 2006, commercial fishing in the United States generated an estimated $4.1 billion in dockside revenues alone (NMFS, 2009a). Their contribution to local economies adds considerably to this value. Additionally, sport fishermen spent $5.8 billion on recreational trips in 2006, which generated $82 billion in associated sales and supported over 500,000 jobs (NMFS, 2009a). Healthy coastal and ocean habitats also provide numerous indirect benefits such as maintenance of water quality and protection from storm damage and erosion, which can save coastal communities billions of dollars in reconstruction and restoration costs.

The HAIP provides guidance to develop the sound science needed to ensure the success of NOAA's mandate of sustainable fisheries and healthy marine ecosystems. Fulfilling NMFS' mandates to manage fishery species and other LMR's must be based on a scientific understanding of the relationships among species and their habitats, and of the dependence of marine ecosystems, and ultimately sustainable fishery yields, on the extent and condition of these habitats. In addition, full implementation of the HAIP ultimately should reduce the impacts of litigation to NOAA, thereby allowing decision-makers to focus limited resources on our most pressing scientific and management needs.

Defining NMFS' Habitat Assessment Mandates

NOAA's mission is to understand and predict changes in Earth's environment and conserve and manage coastal and marine resources to meet our nation's economic, social, and environmental needs (NMFS, 2007). NMFS, an agency of NOAA, is the principal steward of fishes within the U.S. exclusive economic zone (EEZ; generally from 3 to 200 nautical miles offshore). NMFS also provides advice on the conservation and management of fishery species within territorial and international waters.

Major U.S. Habitat-Related Legislation

- Magnuson-Stevens Reauthorization Act
- Endangered Species Act
- Marine Mammal Protection Act
- Coral Reef Conservation Act
- Marine Protected Areas Executive Order

NMFS receives its stewardship responsibilities from a number of Federal laws, many of which include legislation related to the protection, conservation, and restoration of marine, estuarine, and anadromous fish habitats (Appendix 1). Much of NMFS' habitat-related research and science is directed by the MSRA of 2006,[1] which states:

> "One of the greatest long-term threats to the viability of commercial and recreational fisheries is the continuing loss of marine, estuarine, and other aquatic habitats. Habitat considerations should receive increased attention for the conservation and management of fishery resources of the United States."[2]

To this end, the MSRA declares that any Fishery Management Plan (FMP) may include management measures to conserve target and nontarget species and habitats, considering a variety of ecological factors affecting fishery populations.

EFH provisions in the MSRA form the cornerstone of NMFS' mandated habitat responsibilities with respect to fisheries (Appendix 2). EFH provisions were added to the MSRA through the Sustainable Fisheries Act of 1996.[3] EFH is defined as "… those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity."[4] The MSRA requires that FMP's: 1) identify and describe EFH; 2) minimize adverse effects of fishing on EFH to the extent practicable; and 3) identify other actions to conserve and enhance EFH. The MSRA further requires that Federal agencies consult with NMFS on actions that may adversely affect EFH, and that NMFS provide conservation recommendations to those agencies.

Deep-sea coral (DSC) habitats receive special protections under the MSRA, which provides NOAA with additional science and management authorities related to these unique communities. Biogenic habitats such as DSC communities have been identified as hot spots of biodiversity and as EFH for managed species in some regions. These habitats can be particularly vulnerable to some types of fishing gear in contact with the seafloor. Understanding the distribution of DSC and their functions in benthic ecosystems will assist in the conservation and management of our fisheries and LMR's.

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[1] U.S. Public Law 109-479.
[2] 16 U.S.C. 1801(a)(9).
[3] U.S. Public Law 104-297.
[4] 16 U.S.C. 1802(10).

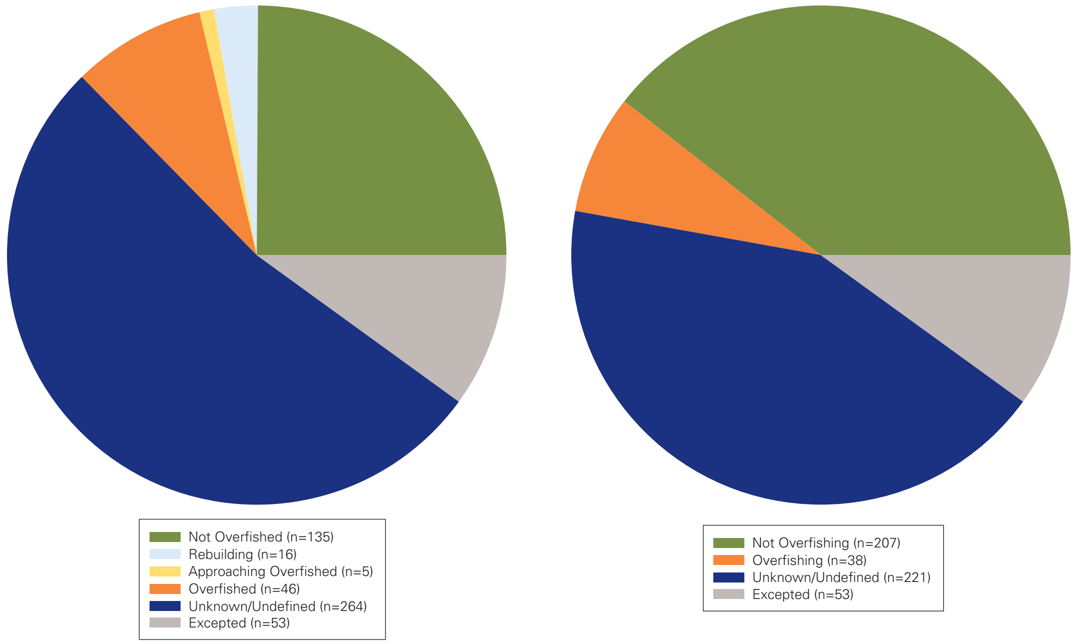


Figure 1
Status of FMP stocks in quarter 3 of 2009. Left, overfished status (relative to biomass targets). Right, status with respect to overfishing (relative to fishing mortality targets). Stocks classified as unknown and undefined have been combined into a single category, as have stocks that have an exception to the application of overfishing criteria.

The MSRA requires NMFS to identify and rebuild those Federally managed stocks that are overfished (i.e. a stock whose biomass level is below its prescribed biological threshold), and to prevent further overfishing. In the third quarter of 2009, 46 of the 519 Federally managed stocks and stock complexes were classified as overfished, five were approaching an overfished condition, and 16 were in a rebuilding status (Figure 1; NMFS, 2009b). While reduction in fishing pressure is essential to rebuild these overfished stocks, characterization and protection of EFH also are important to aid in rebuilding efforts and to encourage enhanced stock production and recovery. However, the information necessary to designate EFH for many Federally managed stocks often is insufficient to support meaningful management measures (COP, 2004).

NMFS' mandates require adequate stock assessments be conducted to determine the status of Federally managed species, with respect to biomass and fishing levels. In the third quarter of 2009, 221 of the 519 Federally managed stocks and stock complexes had an unknown or undefined status with respect to overfishing, and 264 stocks/stock complexes had an unknown or undefined overfished status (Figure 1; NMFS, 2009b), which highlights the need for additional data and resources to successfully meet the mandates of our agency. In particular, habitat-specific information on abundance and distribution at higher spatial and temporal resolutions is necessary to accurately assess the status of many of these stocks, several of which live in complex habitats that are not easily or effectively surveyed with conventional methods (e.g. bottom-trawl gear). In addition, nearly all of the 135 stock assessments that currently are considered adequate under NOAA's stock assessment performance measure (R. Methot, Personal communication[5]) are based solely on demographically derived indices. Stock assessments of only a few of the best-studied species currently use any ecosystem and habitat information beyond simple stratification of the surveys by depth and geographic province, which can be considered crude proxies for more appropriate habitat variables.

[5]Richard Methot, NMFS Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA, 98112.

Recommendations from Independent Reviews

Several independent scientific reviews have emphasized the importance of improved habitat research and data collection to the conservation and management of marine fisheries, habitats, and ecosystems. The U.S. Commission on Ocean Policy (COP, 2004) asserts that, while the NMFS science program has done well in providing biological information to manage single species, agency research has not adequately addressed many pressing questions beyond traditional stock assessment science and fishery biology (e.g. issues related to habitat and multispecies interactions). The COP states that coastal habitat conservation and restoration should be integral to ocean and coastal management, and should be strengthened through: 1) the development of national, regional, and local goals; 2) the institution of a dedicated program for coastal and estuarine conservation; 3) better coordination of Federal habitat-related activities; and 4) improved research, monitoring, and assessment. Coordinated and comprehensive habitat inventories and assessments are considered essential for identifying critical habitats, evaluating the causes of habitat loss and degradation, and setting priorities for conservation and restoration efforts.

The COP (2004) also recommends that NMFS designate EFH using an ecosystem-based approach (Recommendation 19-21). They note that the current single-species approach to designating EFH, with "scant legislative guidance and little scientific information available on habitat requirements," requires the Fisheries Management Councils (FMCs) to be overly broad when defining EFH. Our lack of information on species-habitat associations, coupled with this single-species approach, has resulted in the designation of so much EFH in some cases that the original purpose of identifying areas that deserve focused attention and protection (i.e. truly **essential** habitats) has not been realized. A new approach will require enhanced research programs to improve existing data collection and analytical methods, and to develop additional means of identifying those habitats critical to sustainability and biodiversity goals.

The National Research Council (NRC) has produced a number of reports that consider the current state of habitat information and research, as relevant to NMFS mandates. The authors of "Dynamic Changes in Marine Ecosystems" (NRC, 2006) contend that spatial analyses, in particular, may be one of the greatest challenges to fisheries managers, and that new developments in measurement and analytical methods will allow for explicit consideration of spatial variability in marine systems. Collection of spatially explicit biological data is becoming essential for assessing and monitoring both broad- and fine-scale population trends (NRC, 2006). Furthermore, the NRC report on marine protected areas (MPA's; NRC, 2001) notes that MPAs can function as living research laboratories in which habitat status can be monitored and the sustainability of biological communities and associated fisheries can be evaluated.

Many coastal states have developed action plans to address marine habitat issues of common interest to NMFS and other Federal agencies. The Gulf of Mexico Alliance, including Texas, Louisiana, Mississippi, Alabama, and Florida, released the "Governors' Action Plan for Healthy and Resilient Coasts" (GOMA, 2006). This plan prioritizes identification and characterization of Gulf habitats as one of five key issues. The Gulf of Maine Council on the Marine Environment, representing the governors and premiers of Massachusetts, New Hampshire, Maine, New Brunswick, and Nova Scotia, released a similar plan that identifies habitat conservation as one of three major goals (GOMC, 2008). The "West Coast Governors' Ocean Action Plan" (West Coast Governors, 2008) includes three recommendations regarding habitat: 1) protect the health of ocean and coastal habitats by mapping ecological communities and human uses and characterizing coastal and marine habitats in a comprehensive geographic database; 2) identify key habitats that could benefit from additional or innovative conservation measures; and 3) restore estuarine habitats, including coastal wetlands, to achieve a net increase in habitats and their functions. These and other regional plans highlight the need for ecosystem-level policies that will maintain healthy habitats and species with critical ecological roles in all coastal states.

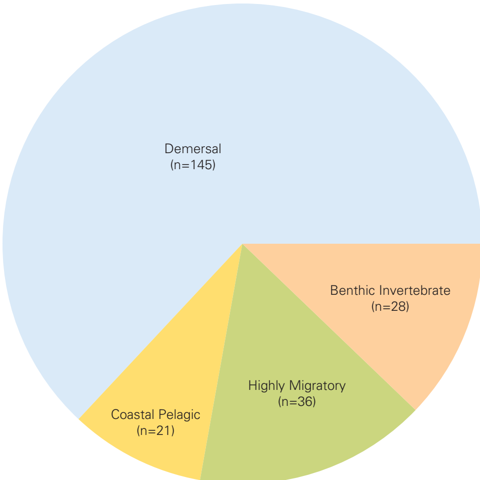


Figure 2
Number of FSSI stocks in four life history categories.

Scope of the Habitat Assessment Improvement Plan

A meeting of experts was held in April 2008 to address the lack of financial support for habitat research within NOAA. Participants included members of the NOAA Habitat Program, NMFS Office of Habitat Conservation (F/HC), NMFS Office of Science and Technology (F/ST), representatives of each of the NMFS Science Centers, NOAA Sea Grant, and others. John Boreman, then Director of F/ST, presented the rationale for much-needed fisheries habitat research and emphasized the necessity to deliver sound habitat assessment science in a form that can be readily applied by fishery managers. He suggested that:

- Habitat science be linked to stock assessments and eventually to IEA's;
- Habitat-related impacts shape natural mortality[6] rates (*M*); and
- An estimate of the fractional reduction in year class strength due to the source of mortality under study is needed from habitat scientists.

From this meeting, the need for an HAIP having a format similar to the successful "Marine Fisheries Stock Assessment Improvement Plan" (SAIP) (NMFS, 2001; Appendix 3) was identified. An HAIP writing team was appointed, comprising one or two representatives from each of the six NMFS Science Centers, F/ST, and F/HC; the first meeting of the new HAIP Team was held in July 2008.

Given the complexity of this task, the scope of the HAIP was restricted to the 519 Federally managed stocks or stock complexes that are included in FMP's, with a particular focus on the 230 stocks or complexes in the Fish Stock Sustainability Index (FSSI) (Figure 2; Appendix 4). FSSI stocks represent about 90% of all commercial and recreational U.S. landings. While the team based the analysis of resource needs on these important stocks, the conclusions and recommendations of the HAIP are relevant to and can be applied more broadly to other managed and protected species. These species occur in marine, estuarine, and freshwater ecosystems that often are affected by significant change to habitats and about which little is known. For example, under the Federal Power Act,[7] NMFS protects diadromous fishes from hydropower development, yet managers do not have even baseline assessments on current or historic habitats. While these species were not specifically included in the HAIP, a better understanding of all habitats will facilitate our ability to implement the best management actions for all LMR's. Future planning efforts should address specific habitat science needs for those LMR's not included in the HAIP (e.g. marine mammals, sea turtles, and non FSSI fish and invertebrate species).

The HAIP builds on the concepts that improvement of the stock assessment process is a high priority for fisheries researchers, and that high-quality habitat science will enhance our ability to identify and implement appropriate management actions to sustain viable fisheries. The HAIP emphasizes the importance of improving survey strategies and stock assessment models and their data input. The recommended research should: 1) determine habitat factors related to spatial and temporal variation in stock production, focusing on life history processes (e.g. dispersal and movement patterns, reproduction, feeding, growth, mortality) that occur during the most critical developmental stages; 2) describe in quantitative terms the role of habitat quality on these critical life history processes and overall stock production; 3) provide scientists with useful habitat information at appropriate spatial and temporal scales to improve design of stock surveys; and 4) provide scientists with habitat information to be used in current stock assessment models or to support model improvements. These activities also will support NMFS man-

[6]For a fish stock, Z (total mortality) = F (fishing mortality) + M (natural mortality).
[7]16 U.S.C. 791-828c.

agement needs to delineate EFH, identify HAPC's, establish and monitor MPA's and similarly managed marine areas, select sites, design and monitor habitat restoration and mitigation efforts, and determine the effects of climate change on fisheries.

Gathering Information for the Plan

The HAIP Team developed two questionnaires to assist in identifying the most important factors hampering NMFS' ability to provide accurate, precise, valid, and defensible habitat assessments and the resources needed to produce such assessments. The first questionnaire was directed at NMFS habitat and ecosystem scientists, population/stock assessment scientists (those who conduct stock assessments and/or surveys of stock abundance), and resource managers from NMFS' six Regional Offices; these scientists and managers should have a clear idea of the primary deficiencies in habitat-related input data and spatially explicit models. One hundred thirty-three scientists and managers responded to all or part of the first questionnaire. The second questionnaire was directed at science program managers, those best suited to give an overview of each Science Center's habitat and population/stock assessment programs. This second questionnaire specifically was designed to determine the resources (e.g. data collection programs, assessment scientists, survey personnel, technicians, database managers, and computer programmers) needed to improve our ability to develop habitat assessments. One response to the second questionnaire was submitted from each Science Center.

The HAIP Team gathered additional input on direction and content of the HAIP during discussions specifically with stock assessment scientists and several briefings to NMFS' leadership, Habitat Assistant Regional Administrators, some FMC's, and other staff of Science Centers and Headquarters. These groups also were given the opportunity to review the draft HAIP.

Section 2: The Nature of Habitats

At a Glance

- Habitats, or the place where fishery species live, can be characterized by the physical, chemical, biological, and geological components of our oceans.
- Habitat science is the study of relationships between species and their environment.
- Habitat information is needed in almost every program within NOAA, yet habitat science has received relatively little programmatic support.
- A habitat assessment is both the process and the products associated with consolidating, analyzing, and reporting the best available information on habitat characteristics relative to the population dynamics of fishery species.
- Indicators of habitat value can be developed through a habitat assessment by understanding the relationship between habitat, the productivity of fishery species, and type and magnitude of various impacts.
- Habitats form the structural matrix of ecosystems, and habitat science can be the bridge between single-species stock assessments and multispecies IEA's.
- Understanding and predicting the effects of climate change and other anthropogenic impacts on marine resources and associated ecosystem services will require an increased emphasis on habitat science.

What Is Habitat?

Habitat is the place where an organism lives, and species define their habitat by their spatial and temporal distributions. It is commonly misconstrued that fish habitat refers only to benthic substrata, yet few species are strictly benthic or pelagic but rather use multiple habitat types even within a single stage in their life history. Thus, we recognize that habitat for any single species or group of species could include the physical, chemical, biological, and geological components of both benthic and pelagic realms.

The boundaries of an ecosystem are defined by combining the habitats of a community of organisms. Accordingly, habitats form the structural matrix of an ecosystem. Although species define their own habitats, we identify important habitat characteristics by observing associations between the species and their environment.

Measuring the associations among species and their habitats on various spatial and temporal scales is essential to determine the relative importance of types and combinations of habitats in structuring communities. For example, geomorphology, depth, and rugosity explain much of the variability found in the local distribution and abundance of demersal fishes (Love and Yoklavich, 2006; Stephens

SWFSC

Habitat includes the physical, chemical, biological, and geological components of both benthic and pelagic realms.

Habitat Characteristics Important to Marine Species

Seafloor Structure
- Vegetation
- Emergent epifauna
- Biogenic reefs (e.g. coral, oyster, sponge)
- Geomorphology (e.g. rocky outcrops, pinnacles)
- Physiography (e.g. seamount, submarine canyon)

Sediments
- Grain size
- Organic content
- Rugosity
- Stability
- Slope

Hydrodynamic Processes
- Currents/boundaries/fronts
- Tidal dynamics
- Wave dynamics
- Upwelling

Hydrology
- Depth/bathymetry
- Salinity/haloclines
- Temperature/thermoclines
- Density/pycnoclines
- Turbidity
- Nutrients
- Dissolved oxygen/oxyclines
- pH

Anthropogenic Alterations
- Pollutants/contaminants
- Artificial structures (e.g. artificial reef, oil platform)
- Created habitats (e.g. restored salt marsh, planted seagrass bed)
- Fishery impacts
- Marine debris

et al., 2006), and the habitat of highly migratory species of billfishes is delineated by gradients in dissolved oxygen in the upper ocean (Prince et al., 2009). Species respond to their environment at various spatial and temporal scales (Anderson and Yoklavich, 2007; Ault and Johnson, 1998), thereby making a range of choices in occupying specific habitats. In this way, habitats can modify the distribution and movement of a species and the interactions among species, and ultimately can provide ecological benefits to their reproduction, growth, and survival.

What Is Habitat Science?

Habitat science is the study of relationships between species and their environment. The relative importance of habitat characteristics for a species can be identified by distribution and abundance patterns in time and space and by rates of growth, mortality, and reproduction. All of these measures can be related to fishery productivity and used as indicators of habitat value.

Habitat science is not synonymous with ecosystem science, but habitats form the structural matrix of ecosystems, and an understanding of geospatial associations of species and their habitats can be one of the first steps in producing IEA's. The HAIP team considers habitat science and assessments as a bridge between single-species stock assessments and multispecies IEA's (Figure 3). Despite this conceptual linkage, systematic integration of these three central scientific endeavors of NMFS – stock, habitat, and ecosystem assessments – has been lacking. Without planning and coordination among these efforts, the strength of collective results is greatly diminished.

Habitat science, while currently conducted on a limited basis throughout NOAA, is an integral component of almost every program (Figure 3). NOAA's ability to conserve trust resources and assess potential environmental impacts requires an understanding of how habitats support LMR's. Habitat science directly informs NMFS' efforts to identify and protect EFH. Effective habitat restoration depends on habitat science to identify appropriate sites, to design functional habitats, and to monitor habitat response. Similarly, habitat science is used to understand potential effects of MPA's, climate change, and coastal and offshore energy and aquaculture development.

Improving habitat science is a major goal of many NMFS strategic planning documents. "Expand science-based knowledge to more effectively assess, protect, and restore important coastal and marine habitats" is one of four primary goals in the "NOAA Habitat Program: NMFS Strategic Plan 2009-2013" (NMFS, 2009c). A goal of "NMFS' Strategic Plan for Fisheries Research" (NMFS, 2007) is to provide scientifically sound information in support of EBFM. Habitat science is vital to such an ecosystem-based approach to management, and considerable research will be needed to implement holistic EBFM. Most particular

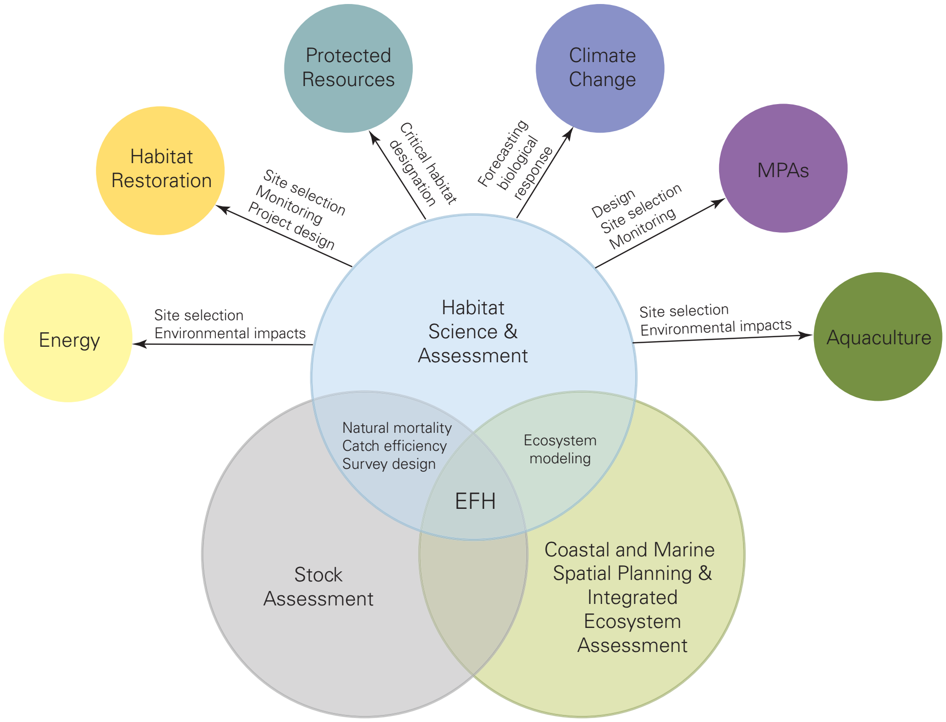


Figure 3

Linkages among habitat science and assessments and other components of ecosystem-based fishery management within NOAA. Examples of how habitat information can be used in these components are listed along the arrows and in circle intersections.

to NMFS, there has been little habitat research directed toward improving stock assessments. The availability of habitat data will help achieve the highest tier (SAIP Tier 3) of stock assessments, which calls for the explicit incorporation of ecosystem considerations (e.g. multispecies interactions and environmental effects, fisheries oceanography, and spatial and seasonal analyses; NMFS, 2001).

The HAIP specifically addresses these shortcomings and presents a focused habitat research program to provide the science that will help to integrate stock assessments into ecosystem assessments. Successful EBFM, as well as improved EFH conservation and management, depend on NMFS making this connection.

What Is a Habitat Assessment?

A habitat assessment (Figure 4) is both the process and the products associated with consolidating, analyzing, and reporting the best available information on habitat characteristics relative to the population dynamics of fishery species and other living marine resources. The ultimate goal of a habitat assessment is to determine the function of habitats in relation to fishery production and ecosystems, thereby supporting management decisions that are a mandated responsibility of NOAA.

In a habitat assessment, spatial and temporal relationships of environmental data (e.g. ocean and climate properties, seafloor substratum types, water depth) with species by life stage are used to determine types, distribution, and amount of habitats that support fishery stocks. Evaluating the function of these habitats ultimately can include measures of habitat-specific vital rates such as growth, maturity, fecundity, and mortality, as well as patterns and rates of species movement among habitats.

Important habitat components can be identified from these data and linked to sources of impacts and associated management options. The establishment of meaningful baseline conditions is critical to understand environmental impacts but can be difficult, largely due to lack of historic data. However, this should not forestall the advancement of habitat assessments. One key

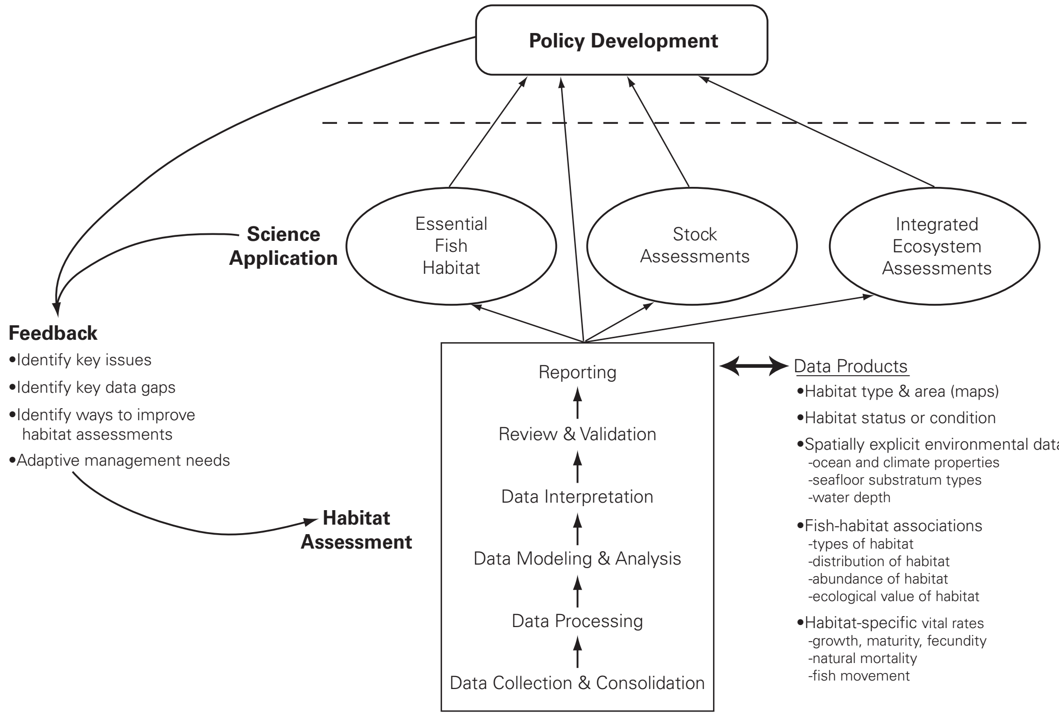


Figure 4

Flow diagram of the mechanics (development, application, and improvement through feedback) of a habitat assessment. Dotted line illustrates the distinct separation of science and policy development during the assessment process.

outcome of an assessment is a gap analysis, by which research and data necessary to improve the assessment are identified and prioritized. The habitat research that improves assessments and the periodic review of assessments both lead to adaptive management.

These assessments should provide the basis for sound habitat management and policy. To ensure quality and integrity, the science side of the process should be the domain of the Science Centers, while Regional Offices and FMCs determine management policy (Figure 4). A science-based assessment should be independently developed to feed into the separate public policy process, similar to the approach used for stock assessments that inform FMC decisions (see Figure 7, p. 23) and marine mammal assessments that inform findings following from the Marine Mammal Protection Act and the Endangered Species Act (ESA). Given that management decisions often are contentious, and can have important effects on ocean activities, independent defensible assessments are critical. Feedback from the policy side of this process can be used to direct research and fine-tune future assessments.

Habitat Assessments and Climate Change

Climate change is affecting coastal and marine ecosystems and the habitats they contain, and it is highly probable that the rates of these changes will increase in the foreseeable future (Intergovernmental Panel on Climate Change, 2007). Impacts attributable to climate change include: increasing ocean temperatures; sea level rise and subsequent inundation of low-lying habitats; ocean acidification; loss of sea ice; changes in the quantity, quality, and delivery of fresh water; and severe alterations to weather patterns and possibly to ocean circulation (Griffis et al., 2008). Furthermore, the geographic range of some fish stocks are shifting as a result of climate-driven change to habitat conditions (Murawski, 1993; Perry et al., 2005), which may result in the development of new fisheries in places like the Arctic. Consequently, habitat assessments need to be placed in the context of the varied effects of climate change.

Commander Richard Behn, NOAA Corps

Loss of sea ice and other impacts of climate change may be extreme in the northern seas and result in shifts in the geographic range of fish stocks and the possible development of new fisheries in places like the Arctic.

As consensus on the reality of climate change has emerged, mandates and programs of many science and management agencies are evolving to meet the new challenges. Concurrent with the development of the HAIP, NOAA has begun developing strategies to better meet its mandates as both a producer and a user of climate information. NOAA's needs, as relevant to climate change, have been identified as: baseline information, including integrated biological and climate observations; research and modeling of adaptive capacities of species and ecosystems and of physical and chemical changes of the oceans; and enhanced integration and capacity of programs within and beyond NOAA, including new tools for risk assessment and scenario planning to evaluate management options (Griffis et al., 2008). Many of these needs are directly related to habitat science and assessments.

To serve fishery management needs, NMFS' habitat assessments must consider the consequences of climate change to the affected habitats and on the fishery resources that depend on these habitats. The pace, scale, and ecological impacts of climate change could introduce additional levels of uncertainty, leading to an increased need for habitat assessments. To address these issues, habitat scientists will need to:

- Establish field and laboratory programs necessary to monitor long-term indicators for key habitats and species;
- Understand the effects of change in environmental factors (e.g. temperature and acidification) on habitats and species distribution, reproduction, growth, and survival;
- Synthesize the data in integrated physical, chemical, and biological models; and
- Provide advice and tools to inform managers of climate impacts on habitats and managed species.

Section 3: How NMFS Can Use Habitat Assessments

At a Glance

- Habitat assessments and associated data products can and should be used for: EFH designation; habitat conservation and management (including implementation of MPA's); improved fishery-independent population surveys and stock assessments; and CMSP and IEA's.
- Limited habitat data constrain NMFS' ability to effectively designate EFH and prioritize habitat protection, restoration, and mitigation.
- Most stock assessments currently lack integration of habitat data, despite the potential for habitat data to reduce uncertainty in estimates of species abundance and in the way population dynamics are modeled.
- Most stock assessment biologists surveyed by the HAIP Team thought that habitat-specific stock assessments would require at least some modification of existing models, if not entirely new models.

Habitat assessments should form the underlying scientific basis for decisions on habitat management and protection. Data products from habitat assessments include maps of habitat type, extent, and condition; these products, combined with habitat-specific fish distribution (EFH Levels 1-2 as described in the EFH regulatory guidelines; Appendix 2) and vital rates (EFH Levels 3-4) support EFH designations and protection. Components of habitat assessments also can assist in advancing our ability to accurately assess fishery stocks, particularly by: 1) using associations of fish densities, size distributions, and habitat characteristics to improve the design of fishery resource surveys and resultant estimates of population abundance; 2) developing catchability coefficients (q) for different habitats; and 3) estimating habitat effects on natural mortality (M) to improve population dynamic models. These and other components of habitat assessments can be incorporated into Tier 3 – Next Generation Stock Assessments as prescribed in the SAIP (NMFS, 2001).

Habitat assessments and the science supporting them have a major role in the design and management of MPA's, which are intended for conservation of fishery resources and the ecosystems that support them. Documenting and monitoring the extent and condition of habitat types, and the relationships between fish population dynamics and habitats, are necessary to ensure effective MPA's. Once an MPA is established, it can have significant effects on the behavior of associated fishing fleet(s) and on the dynamics of affected stocks. The redistribution of fishing effort can introduce a new component of spatial heterogeneity into the vital rates of fish stocks, including fishing mortality, size and age distribution, and fecundity. These new aspects of spatial heterogeneity should be included in stock assessments, which in turn will drive new requirements for fish surveys and stock assessment models.

Ultimately, CMSP and the development of IEA's will greatly benefit from information produced in habitat assessments, and EBFM necessitates an understanding of the associations among the habitats and species in the ecosystem. All of these uses of habitat assessments (i.e. EFH, stock assessments, CMSP, and IEA's) have the potential to incorporate information relevant to climate change and other anthropogenic impacts on habitats, associated ecosystem services, and management options.

Resource managers are turning increasingly to the concept of ecosystem services as part of their decision-making processes (Daily et al., 2009; NRC, 2005). Examples of services derived from functional coastal and marine habitats include: food from fisheries; nursery grounds; coastal protection from erosion or inundation; value of recreation and tourism; energy from waves and tides; carbon storage and sequestration; water filtration; phyto-remediation; and aesthetic and existence values. Habitat science and habitat assessments hence should provice fundamental inputs to ecosystem models and their application in projecting ecosystem services.

Habitat Management

EFH Identification and Conservation

Human-induced impacts on fish habitat can be direct or indirect, and may stem from activities such as fishing, shipping, aquaculture, mining, coastal development, and climate change. To conserve and protect these habitats, the MSRA requires NMFS and the FMC's to designate EFH for Federally managed species and to minimize fishing effects on EFH as practicable in FMP's. NMFS and the FMC's also are required to review the science that supports EFH management actions every five years, and to consult with other Federal agencies on actions that may adversely affect EFH. More robust and comprehensive habitat assessments will directly result in improved EFH identification and conservation.

EFH regulatory guidance[8] provides an approach to organize and use the best available science for describing and identifying EFH. These guidelines recognize a wide range in types of available information. While the most elementary designation of EFH is based on the distribution of species and habitat types from presence/absence data (EFH Level 1), more developed designations address the value of habitats to fisheries production and require information on habitat-specific densities, growth, reproduction, and survival (EFH Levels 2-4). Information beyond EFH Level 1 currently exists for only a handful of fishery species, and often for only a subset of their life stages (NMFS, In press). Less than half of Federal FMP's contain information above EFH Level 1 for even one life stage of one species. This limited information and the precautionary approach adopted by most FMC's, combined with the large number of managed species and all life stages, have resulted in initial EFH designations that extend over most of the EEZ and coastal waters. Given that information on EFH in FMPs forms the basis for NMFS' habitat management actions related to fishing and nonfishing activities, such broad EFH designations make it difficult to prioritize management efforts. Better habitat data and assessments will improve our ability to distinguish EFH from all other habitats for each managed stock/species.

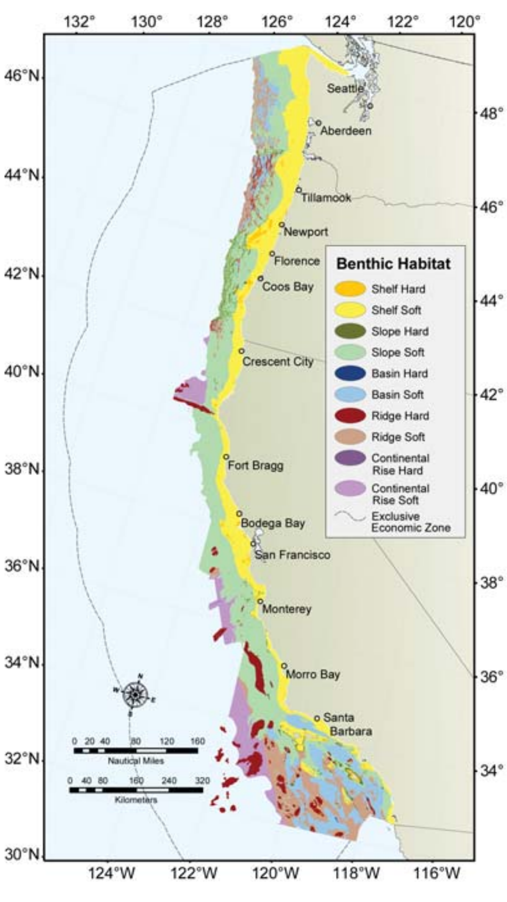


Figure 5

Coast-wide seafloor habitat map used in a risk assessment of groundfish EFH on the Pacific Coast (produced by TerraLogicGIS, Stanwood, WA, with data and interpretations from Goldfinger et al., 2003 and Greene et al., 2003.).

Improved habitat assessments also are important to the FMC's and NMFS as they implement requirements to minimize fishing effects on EFH. These measures may include gear modifications, reduction in fishing effort, and fishing gear restrictions in particular areas. In order to recommend such measures, resource managers need scientific assessments to demonstrate the temporal and spatial effects of fishing gear on habitats and the severity of those effects on LMR's. Integration of these analyses of gear impacts into broader assessments of habitat extent, condition, function, and threats will result in more effective habitat protection.

As an example, NMFS conducted a habitat assessment as part of the final Environmental Impact Statement on EFH designation and minimization of adverse impacts to the habitats of 82 species of west coast groundfishes, including 40 FSSI stocks (NMFS, 2005a). This assessment included innovative habitat suitability and risk models, an internet-based habitat-use database, and the first step in the development of seafloor habitat maps for the entire west coast (Figure 5; Copps et al., 2007). This assessment also represented a compilation of information on the status of habitats important to groundfishes and the impact of fishing on those habitats (Figure 6).

[8]50 CFR 600.905.

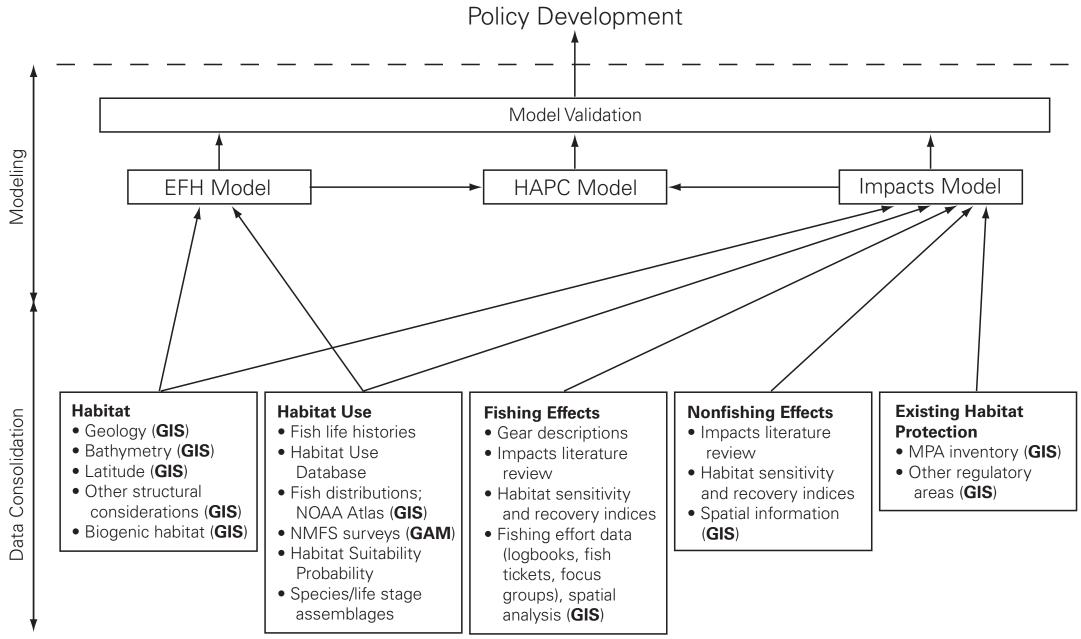


Figure 6

Decision-making framework to guide the science-based habitat assessment (efforts below the dotted line) and policy development for West Coast Groundfish EFH (modified from Copps et al., 2007).

While lacking information on the contribution of habitats to the productivity of fish populations and the capacity of specific habitats to recover from various types of fishing impacts, the assessment provided the scientific justification for proposing and implementing several significant management measures to protect EFH from fishing. These include a long-term reduction in fishing pressure and the designation of large fishery closures along the U.S. west coast, which will improve our understanding of the use of MPA's to manage fisheries and result in increased protection of sensitive seafloor habitats and associated species.

Similar but more qualitative or less spatially explicit approaches to the compilation of scientific information on habitat vulnerability and sensitivity have been used by the North Pacific, New England, Gulf, and Caribbean FMC's. These assessments often were limited by the lack of data on the spatial distribution of habitats, the value of habitats to fish production, and the distribution and magnitude of fishing effort. More comprehensive habitat assessments are needed nationwide to support the protection of EFH from fishing impacts. There will be opportunities to design new habitat assessments or augment existing ones as NMFS and FMC's conduct regular five-year reviews of EFH information.

The MSRA also requires NMFS to address nonfishing impacts to marine habitats through consultations with other Federal agencies on permitted or authorized activities that may adversely affect EFH. NMFS has the opportunity to provide conservation recommendations to avoid, minimize, or mitigate those impacts. The ability of NMFS to convince other agencies to implement our conservation recommendations often depends on direct, quantifiable evidence of impacts based on habitat recovery rates, habitat availability to fisheries, and significance of habitat loss to fisheries.

Such information is sometimes not available for impacts that have been occurring for years, for example dredge and fill activities, dock and pier construction, beach renourishment, mining, and oil and gas development. In addition to these types of on-going impacts, NMFS anticipates a whole new category of nonfishing impacts to habitat, about which we know very little. In 2005, the emergence and widespread application of a new technology to regasify liquid natural gas (LNG) illustrated the consequences of insufficient science to NMFS' effectiveness at conserving fish habitat. The lack of adequate information on the association between the vital rates of fishes and their habitats impaired NMFS' ability to quantify the environmental impacts of offshore LNG processing facilities on fish stocks in the Gulf of Mexico (Appendix 5). This exposed NMFS to considerable political scrutiny of our precautionary and protective recommendation to replace the proposed open-loop system with a less damaging and more expensive closed-loop system. Synthesizing existing information through more rigorous, quantitative habi-

Jed Brown, NOAA Restoration Center

Habitat restoration of a Louisiana salt marsh. The native smooth cordgrass has been replanted to encourage rapid colonization of the area and prevent erosion.

tat assessments will help NMFS protect EFH from nonfishing impacts and identify science needs for future research. The effectiveness of NMFS' efforts to protect EFH depends on the quality of information on habitat value and condition.

Other Habitat Management Applications

Habitat assessments and associated products will support many other management efforts and programs in addition to EFH designation. Assessments are particularly needed to identify, prioritize, and design habitats for restoration (e.g. habitats of declining condition, limited in extent, and/or associated with high fisheries productivity) because the scale of such efforts has recently increased (e.g. $167 million to NMFS under the American Reinvestment and Recovery Act of 2009[9]). For example, understanding the dynamics of salt marshes in the northern Gulf of Mexico has influenced the incorporation of marsh edges into the design of created wetlands (Minello and Rozas, 2002). Furthermore, habitat-specific abundances and vital rates could provide the quantitative information managers need to evaluate potential increases in stock production as a result of habitat restoration (Rozas et al., 2005). Demonstrating the impact of restoration efforts in terms of increased number or biomass of fishes has more ecological significance than the current measures of effectiveness based on program effort (e.g. number of projects funded, number of stream miles opened).

Habitat assessments also may form the basis for mitigation recommendations that support EFH consultations or Damage Assessment, Remediation and Restoration Program studies and decisions. These efforts require data on the economic and ecological value of affected habitats. Products of habitat assessments, such as accurate mapping of habitats, are essential for managers to determine habitat loss and identify appropriate areas for mitigation efforts. Habitat-specific abundance and vital rates provide the data needed to calculate change in fish productivity due to environmental damage. Because these data form the basis for requests for mitigation (e.g. compensation required, identification of similarly productive habitats for protection and restoration), well-founded habitat assessments ultimately will result in more effective, defensible management actions.

Habitats and Stock Assessments

As described in the Marine Fisheries Stock Assessment Improvement Plan (SAIP) (NMFS, 2001; Appendix 3), a stock assessment is:

> "…the process of collecting, analyzing, and reporting demographic information for the purpose of determining the effects of fishing on fish populations [Figure 7]. The production of stock assessments requires quantitative information on relative or absolute magnitude of a fish population, estimates of the total removals due to human activities (due to fishery landings, discarded bycatch, and cryptic mortality due to encounters with fishing gear), life history data including rates of growth, average age of onset of sexual maturity, maximum longevity, and the proportion of each age group dying each year due to natural causes, and other factors that affect stock productivity. These data are combined using simple or complex mathematical models to derive best estimates of vital statistics such as historical and recent trends in the number and biomass of the resource, recruitment levels

[9]U.S. Public Law 111-5.

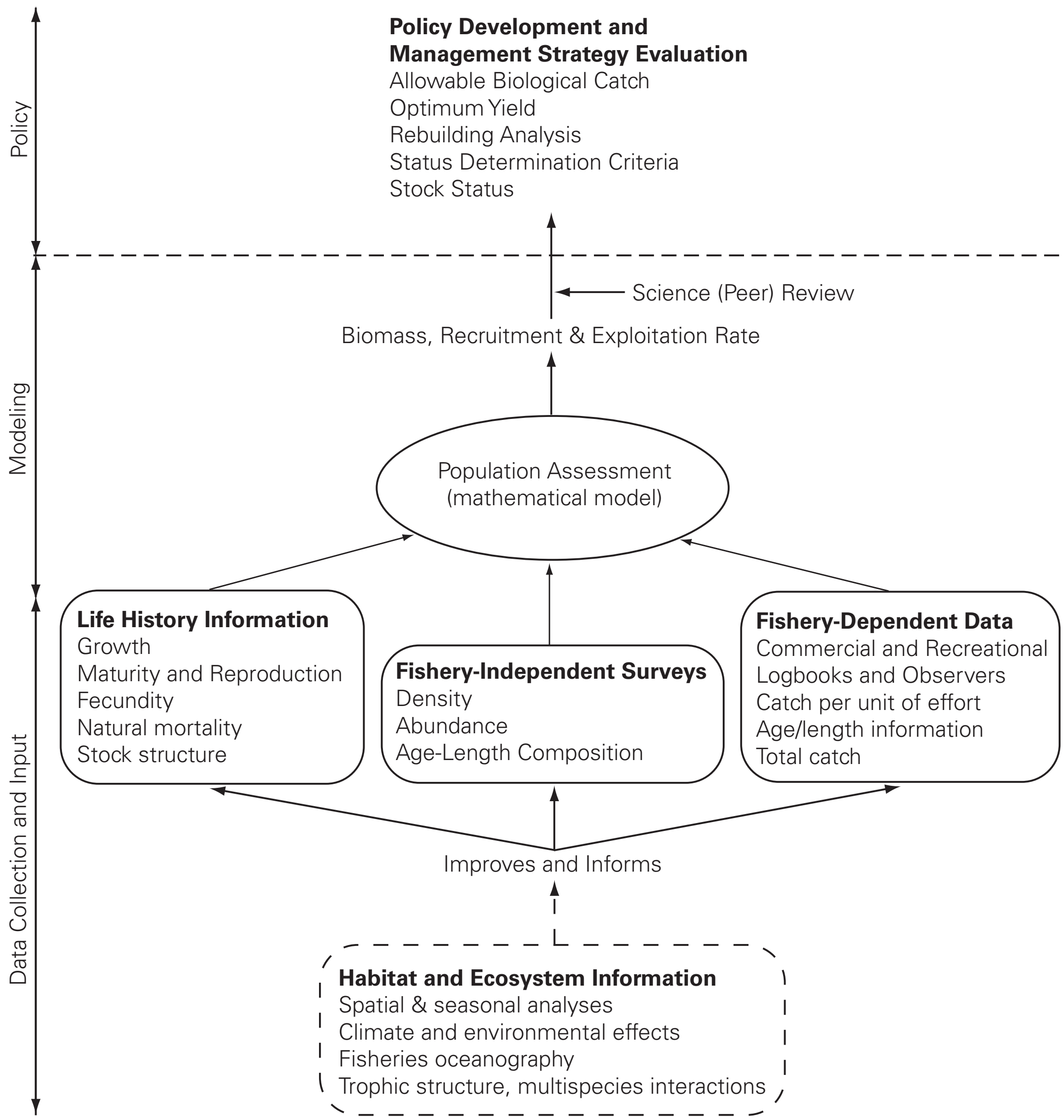


Figure 7

Diagram outlining the fisheries stock assessment process, with data collection and modeling on the science side (below the dotted line) and policy development and management strategy evaluation above the line. Habitat and ecosystem information, while not yet commonly used, can inform and improve assessments for many stocks.

> (number of small fish entering the fishery each year), and the fishing mortality rate or the fraction of the stock alive at the beginning of the year that are killed by fishing (commonly referred to as the exploitation rate). The results of stock assessment calculations provide information necessary to estimate the current abundance and exploitation rate of resources in relation to predefined goals for these two attributes, also termed 'status determination criteria'. ...In addition, assessment results provide the technical basis for setting the level of biologically acceptable yield for healthy stocks, and the expected rate of rebuilding for depleted stocks.... The quality of a particular stock assessment (i.e. the accuracy and precision of stock size and exploitation rate estimates) is directly related to the quality and completeness of the input data used for the assessment. ...improving the quality of fish stock assessments primarily involves improving the quality of basic input data on catches, abundance and life history..."

In the absence of rigorous quantitative data, qualitative information on habitat and ecosystem considerations can be used to inform stock assessments and guide management decisions. However, such qualitative data sets have not been fully incorporated into many stock assessments. One exception is the Ecosystem Considerations Report included in Stock Assessment and

Fishery Evaluation reports published for each FMP under the jurisdiction of the North Pacific FMC. These reports include information on fishing effects on ecosystems, trends in climate and physical environment, and climate effects on ecosystems. Improved habitat data, even if not at a level or resolution that can be directly integrated into a stock assessment model, will contribute significantly to qualitative assessments of stock and ecosystem health.

The precautionary approach is a guiding principle in marine resource management. This approach prescribes conservative management when scientific uncertainty is high. Improved information on the value of habitats for fishery species will reduce this uncertainty. However, certain types of scientific data will reduce uncertainty in habitat, stock, or ecosystem status more than others (Figure 8a), and an important challenge will be the determination of the costs and benefits of data acquisition. For example, the SAIP (NMFS, 2001) recommends monitoring of catch, life history data, and fisheries-independent surveys of abundance as information that will strongly reduce uncertainty in a stock assessment. Other types of data might fall in the zone of diminishing returns, whereby the cost of collecting such information surpasses any reduction in uncertainty. The SAIP notes that habitat and ecosystem information potentially is useful, moving stock assessments from SAIP Tier 2 to Tier 3. While habitat data can improve many stock assessments, the utility of this information varies for different stocks.

Life history variation will influence the value of different types of habitat data. For example, benthic habitat characterization naturally should be more predictive of stock status for demersal fishes, while oceanographic characteristics such as sea surface temperature (SST) likely would be more predictive for pelagic fishes. Both demersal and pelagic fishes may be sensitive to hydrodynamic patterns (e.g. currents) at certain periods of their life cycles, and therefore this information might have intermediate utility for both (Figure 8b). By extension, certain approaches to integrating these types of data into stock assessments could reduce uncertainty better than others.

Fishery species exhibit a wide range of life histories and have developmental stages that occur in very different habitats, both of which have consequences for the incorporation of habitat data into stock assessments. For example, penaeid shrimp in the Gulf of Mexico, like many estuarine-dependent species, have a life cycle that is relatively short in duration (approximately 1 year) but extends over a large geographic range (Cook and Lindner, 1970). The adults spawn offshore and the demersal eggs and planktonic larvae occur in shelf waters. Larvae are carried by currents and tides to shallow estuarine habitats where postlarvae settle and grow through the juvenile stage. Subadults then migrate into open bays and return to offshore habitats. Survival rates vary

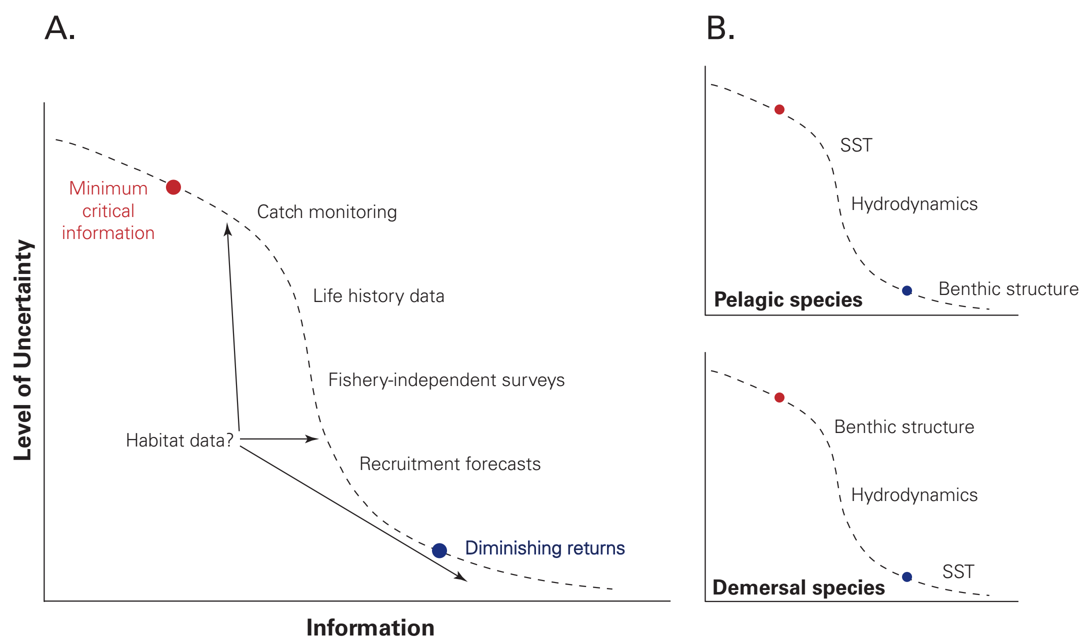


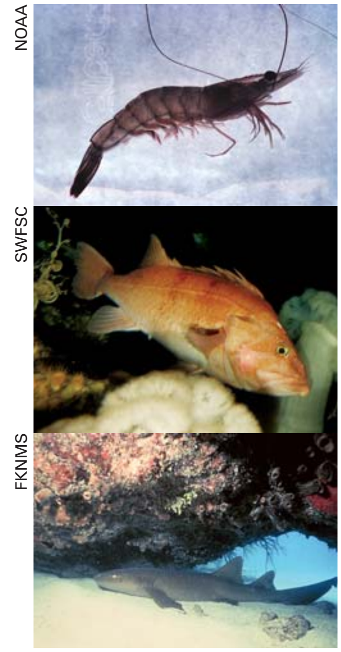
Figure 8

a) The level of uncertainty in stock size can be reduced by various types of information, including habitat data.
b) Particular types of habitat data may be more effective than others in reducing the level of uncertainty in stock size, depending on the life history (e.g. pelagic vs. demersal) of the stock.

for each stage, and associated habitats can affect these rates. Fishing mortality generally does not occur until the subadult and adult stages, but a life history analysis suggests that over 99.99% of shrimp mortality occurs before they recruit to the fishery (Baker et al., 2008).

In contrast, most of the 65+ species of rockfishes (genus *Sebastes*) off the U.S. west coast and Alaska have a relatively long life cycle, with some species living over 100 years. Rockfishes, in general, are highly fecund live-bearers that go through larval, juvenile, and adult stages in approximately the same geographic location but in different habitats (Love et al., 2002; Tolimieri and Levin, 2005). Most larvae are pelagic over continental shelf waters, settling to benthic habitats in relatively shallow water and moving deeper as they grow and mature. Older segments of the population for many of these species live in high-relief rocky areas that are inaccessible to standard trawl gear, while the younger segments are more easily sampled during such surveys.

Sharks and other elasmobranchs provide yet another example of fishery species with widely different life histories. While many sharks are long-lived (like rockfishes) and range over large geographic areas during their life cycle (like shrimp), their life history strategy is quite different from teleosts or crustaceans. Sharks generally have low fecundity rates with annual litters of only a few offspring, and natural mortality in early developmental stages is relatively low. Thus, habitat-related changes in mortality can be quite different from other species (Garcia et al., 2007; Heppell et al., 1999). In addition, vulnerability of these stocks to exploitation can strongly depend on vital rates during different life stages (Cortés, 1998, 2002).



Examples of fishery species with a wide variety of life histories. Top, white shrimp; middle, cowcod (rockfish species); bottom, nurse shark.

It is apparent from just these three types of stocks that life histories of fishery species can be vastly different (Houde, 1987; Cortés, 2000). Similarly, the effects of habitats on fishery populations can be quite variable because of their relation to life history patterns. Thus, uncertainty related to habitat use and habitat change may vary greatly among stocks. Further, understanding habitat associations on the spatial and temporal scales relevant to the stock will assist in the interpretation of variability in our generally broad-scale survey data.

Three Tiers of Assessment Excellence to improve our Nation's stock assessments have been described in the SAIP (NMFS, 2001; Appendix 3). The highest tier (SAIP Tier 3) calls for explicit incorporation of ecosystem considerations, such as multispecies interactions, environmental effects, fisheries oceanography, and spatial and seasonal analyses, into stock assessments. Improvements in the collection and availability of habitat and ecosystem data will help us achieve SAIP Tier 3 assessments.

Below, we discuss several ways that habitat information can inform, and hopefully improve, stock assessments. We stress that habitat data will not necessarily reduce uncertainty for all stocks in all the ways described. Not all approaches are appropriate for every stock, and other improvements, independent of habitat data, will likely improve stock assessments. These caveats point to a need to prioritize those stocks assessments that are likely to benefit from habitat data, and to an independent effort to clarify requirements for SAIP Tier 3 stock assessments.

Habitats, Survey Design, and Estimates of Stock Size

Many fish stocks have strong affinities to specific characteristics of their habitat, resulting in patchy spatial distributions in abundance. Sample stratification or otherwise explicitly incorporating these habitat characteristics into survey design can increase precision and accuracy of estimated densities (Anderson et al., 2005; Ault et al., 1999). Coupling these habitat-specific fish densities with maps of habitat across large areas can be used to improve estimates of stock size (Ault et al., 2005; Yoklavich et al., 2007).

Improved geophysical methods and remote sensing have resulted in detailed maps of surficial seafloor geology. Within U.S. large marine ecosystems, there are ongoing or developing efforts to create geographic information systems (GIS) databases for benthic habitats interpreted from these maps (e.g. Greene and Bizzarro, 2003; Lundblad et al., 2006; NCDDC, 2009; Noji et al., 2004; Parke, 2007; Poppe et al., 1989; Romsos et al., 2007; Sheridan and Caldwell, 2002). These GIS databases capitalize on many years of data collection and mapping from numerous sources. These databases represent some of the first coast-wide delineations of seafloor habitat types and, at a minimum, indicate the distribution of rocky and unconsolidated substrata. These maps and underlying GIS databases are critical to NMFS' efforts to incorporate habitat into survey design and stock assessments.

A variety of census techniques and stratification strategies may be required, depending on the species and habitat associations (Table 1). Traditional bottom-trawl surveys are conducted by NMFS in several regions and provide critical fishery-independent data on the distribution, abundance, size- and age-structure, and reproductive status of many demersal stocks. For example, trawl surveys of walleye pollock in the Gulf of Alaska have as many as 49 strata based on habitat features (Dorn et al., 2008). Even in the absence of detailed habitat data, trawl catches are expanded to abundance based on coarse habitat zones (i.e. Eastern Bering Sea shelf, Eastern Bering Sea slope, and Aleutian Islands) in the stock assessment of skates in the Bering Sea and Aleutian Islands (Ormseth et al., 2008).

Advancements in technology allow scientists to collect new types of data during traditional NMFS surveys. Environmental sensing packages increasingly are being attached to trawls and record a full array of environmental parameters (e.g. depth, temperature, salinity, dissolved oxygen, chlorophyll fluorescence, and turbidity). Additional sensors for light parameters also are being used on trawls (Kotwicki et al., 2009). The new series of state-of-the-art Fishery Survey Vessels (FSV's) currently being

Table 1
The relation of habitat data to observations and biological processes tracked in stock assessment models.

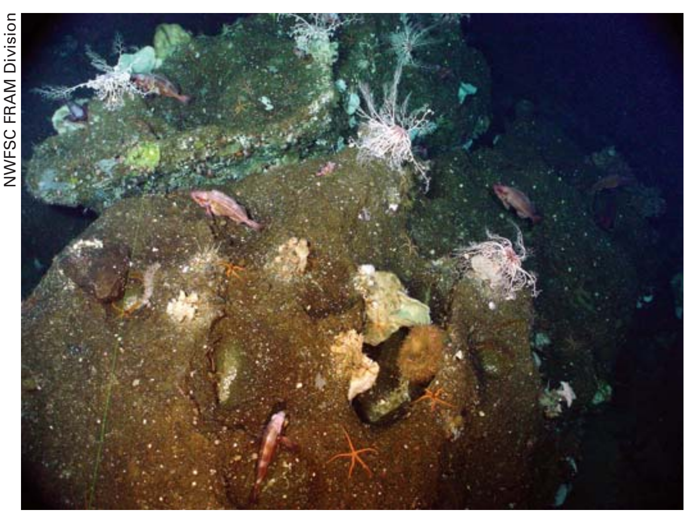
	Stock Assessment Parameters or Equations	Examples of Relevant Stock Assessment Models	Effects of Habitat	Examples from Stock Assessments or Other Studies
Observations				
Abundance	CPUE	All	Stratification across habitats	Habitat-based visual survey for cowcod (Yoklavich et al., 2007) Habitat-stratified visual census for mutton snapper (SEDAR, 2008)
Catchability	*q*	ASPIC SS ADAPT	Unfishable areas Gear selectivity Migration; vertical and horizontal movements	Temperature-dependent *q* for arrowtooth flounder (Wilderbuer et al., 2008a) and other flatfish stocks
Biological Processes				
Natural mortality	*M*	ASPIC SS ADAPT	Variation in mortality rate within a life stage Age- or size-specific variation due to ontogenetic change in habitat use	Habitat-dependent mortality of red drum (Levin and Stunz, 2005) Mortality varies with habitat-dependent life stages (Boreman, 1997; Houde, 1987, 1997)
Density dependence	Logistic, Beverton-Holt, or Ricker functions	ASPIC ADAPT SS	Variation in productivity Variation in carrying capacity	Habitat-dependent recruitment in sablefish (Schirripa, 2007)
Migration and other movements	Constrained logistic function specifying age-specific migration	SS	Spatial heterogeneity Ontogenetic shift in habitat use	Integrating MPAs into stock assessments depends on movement (Field et al., 2006)
Growth	Von Bertalanffy equation	SS	Environmental variation in growth rate	Effects of SST and chlorophyll on growth of anchovy (Basilone et al., 2004)

added to the NOAA fleet are equipped with a variety of technologically-advanced survey tools including high resolution, multibeam sonar that can be used to image both the water column and the seafloor. These tools, if fully employed, will significantly increase capacity for acoustic surveys and benthic habitat mapping as well as improve environmental data collection during fisheries surveys. Across all of the Science Centers, improved environmental sensing capabilities during both bottom trawl surveys and pelagic acoustic surveys have led to collaborations with academic partners and with developers and manufacturers of advanced sampling technologies.

Further, survey and habitat scientists are collaborating on the collection of oceanographic habitat data along with trawl survey data. For example, in addition to recording vertical profiles of temperature and salinity in the Northeast (e.g. Taylor and Bascunan, 2001), continuous surface sampling for these variables and fluorescence is regularly conducted during trawl surveys. Plankton also is collected for the entire region, typically 6 times per year; the chief platform for these collections is the trawl survey. The Northeast Fisheries Science Center (NEFSC) also dedicates two to four "habitat cruises" to augment collections of benthic habitat data (e.g. multibeam bathymetry and bottom rugosity), which are accompanied by bottom trawling. Advanced technologies, such as remotely operated vehicles (ROV) and autonomous underwater vehicles (AUV) with acoustic sonar and ichthyoplankton sampling capabilities, often are used during these habitat cruises. Notably, the Ship-of-Opportunity Program (SOOP) at the NEFSC not only collects Continuous Plankton Recorder data (Jossi et al., 2003) but also profiles of salinity, temperature, and pCO_2 for climate studies (Pershing et al., 2005). Although the SOOP program is conducted in partnership with commercial shipping vessels, incorporating this type of program into trawl survey protocol is a consideration. Such opportunities to calibrate stock assessments with habitat data offer a feasible way to forecast and hindcast effects of habitat variation on stocks (Link et al., 2008a).

A challenge common to trawl surveys is the potential bias and uncertainty in estimating fish biomass in high-relief untrawlable habitats. Two recent independent reviews have criticized the data obtained from trawl surveys that do not adequately sample untrawlable habitats along the west coast of North America (GAO, 2004; Mohn, 2006). Consequently, an expanding number of research groups are developing and refining alternative direct-count visual techniques using human-occupied submersibles (Yoklavich and O'Connell, 2008), scuba (Bohnsack et al., 1999), and dropped video camera arrays (Gledhill et al., 2005) to assess fish abundance in habitats that are difficult or impossible to survey with trawls or in areas (e.g. MPA's) where damage to habitat by trawling should be avoided. ROV's and AUV's (Tolimieri et al., 2008) are being evaluated as alternative sampling tools for monitoring fish abundance under some circumstances.

In the eastern Gulf of Alaska, the Alaska Department of Fish and Game has been conducting habitat-based stock assessments for several species of the rockfish complex since 1989 (O'Connell et al., 2007). Biomass is derived from the product of estimated fish density for all rocky habitats, estimated area of rocky habitat, and average weight of fishes from port samples. Density is based on direct-count, line transect surveys conducted from a human-occupied submersible. High-resolution multibeam echosounder data are used to delineate the rocky habitats, thereby reducing uncertainty in the assessment. Other habitat-specific assessments using direct-count survey methods and interpreted habitat maps have been conducted for cowcod in the Southern California Bight (Dick et al., 2007; Yoklavich et al., 2007), spiny lobster in the southeastern United States (SEDAR, 2005), and mutton snapper in the South Atlantic and Gulf of Mexico (SEDAR, 2008). These habitat-based



NWFSC FRAM Division

Rockfishes in high-relief rocky habitat are difficult to survey using traditional methods such as bottom trawls.

assessments are being used by FMC's to set catch quotas and, in some cases, to support stock rebuilding programs. These surveys need to be repeated over time in order to develop temporally informative assessments that can be used in forecasting population abundance.

Semi-demersal schooling species inhabiting rocky untrawlable habitats present a different challenge to habitat and stock assessment scientists, and several Science Centers are evaluating new approaches to this sampling problem. At the Northwest Fisheries Science Center (NWFSC), scientists recently demonstrated the use of local fishermen's knowledge in conjunction with combined acoustical and optical technologies to survey widow rockfish along the U.S. west coast (Ressler et al., 2009). This approach could be applied to other difficult-to-assess schooling species.

Habitats and Catchability

Stock assessment models (e.g. Virtual Population Assessment and Stock Synthesis [SS]) typically use catch, catch rate, and biological information (e.g. length-frequency, age-frequency, fecundity, and maturity) from fishery samples and fishery-independent surveys, as well as auxiliary information on stock-recruitment parameters, ageing uncertainty and bias, and natural mortality (Ianelli and Fournier, 1998; Methot, 1990; Methot, 2009; Somerton et al., 1999) to calculate year- and age-specific survival for each cohort and determine annual change in fish abundance. Fishery-independent surveys of fish stocks (e.g. trawl, acoustic, and direct-count surveys) are essential for estimating fish biomass, modeling the structure of stocks, and setting catch quotas. Most surveys, however, provide information only on relative changes in fish abundance. To estimate true population size, stock assessment models include a critical parameter, the catchability coefficient (q; Sanchez, 1996). This coefficient is a proportionality constant that relates relative abundance to actual stock size. Uncertainty in q can significantly affect the accuracy and precision of biomass estimates. A realistic catchability coefficient likewise is important to alternative approaches, such as estimating biomass empirically from direct-count surveys. This uncertainty weakens management decisions.

Catchability is influenced by several factors, including stock availability and the probability of either being caught or counted directly, depending on the type of survey. Each stock has its own inherent availability and each gear or survey type has its own inherent catchability; both can be modulated by habitat, including an array of environmental variables such as depth, substratum, temperature, dissolved oxygen, and currents. Quantifying the influence of habitat will reduce uncertainty in q and could improve stock assessments by explaining some of the temporal and spatial variability in catch (or absolute counts). A number of stock assessments include habitat-dependent catchability coefficients (Table 1). Several assessments of flatfish stocks in the Bering Sea and Aleutian Islands region of Alaska integrate bottom temperature as a covariate of q (e.g. arrowtooth flounder [Wilderbuer et al., 2008a]; flathead sole [Stockhausen et al., 2008]; northern rock sole [Wilderbuer and Nichol, 2008]; yellowfin sole [Wilderbuer et al., 2008b]). In the stock assessment of Atlantic swordfish, generalized additive models were used to relate catch to environmental variables (convergence zones and depth of mixing) in pelagic areas of the South Atlantic (ICCAT, 2007).

Habitats and Population Dynamics

Most stock assessments rely on models that simulate population dynamics and forecast size of the population (Methot, 2009). Habitat data potentially can be used in population dynamic models in several ways (Table 1): 1) habitats can affect variation in vital rates and changes in body size; 2) habitats can be linked to productivity and capacity parameters in stock-recruit models; and 3) habitats can affect a species' movement. These methods hold promise to advance stock assessments to SAIP's Tier 3 status and to provide an explicit link to the requirements of MSRA for managing stocks and their habitats.

<u>Habitats and Vital Rates</u>: The management of fishery stocks historically has focused on fecundity (how many animals are born) and fishing mortality (how many are harvested), while natural mortality (M) often is assumed to be constant. However, both fecundity and survival strongly depend on size and age (growth); changes in these parameters need to be age- or size-structured and may plateau or decline at extremely high population densities. These vital rate parameters vary among life stages and habitats.

Over the lifetime of a fishery species, natural mortality is much higher than fishing mortality, and both growth and mortality vary among and within life stages due to changing habitat conditions from human and natural influences. In determining acceptable levels of fishing mortality for exploited populations, natural mortality often is assumed to be constant, mainly because of inadequate information on the causes and extent of this variability. An important component of a habitat science program is the evaluation of habitat effects on fecundity, growth, and natural mortality of fishery species. The initial goal of such an evaluation should be to determine the usefulness of additional information on habitats and these vital rates in stock assessments.

The general approach to such an evaluation involves: 1) identifying habitat-specific vital rates within life stages of a species; 2) developing a stage-structured matrix model that requires basic information on vital rates for each stage; 3) using the model to identify life history stages that are sensitive to changing vital rates; and 4) examining relationships among habitats and vital rates for these sensitive life stages.

A stage-based matrix model (Caswell, 2000) is a convenient way to organize information on habitat-specific vital rates for a species. The matrix model requires estimates of fecundity, growth, and mortality (natural and fishing) for each life stage. Growth is used to determine stage duration, and the matrix then provides estimates of survivorship for each life stage. For most managed species, stock assessments have estimated many of the vital rates for stages undergoing fishing. The stage-based matrix model also provides a framework for examining the sensitivity of a population to changes in vital rates during any particular stage (Greene and Beechie, 2004; Levin and Stunz, 2005; Mangel et al., 2006; Quinlan and Crowder, 1999). Information on how habitats affect growth and mortality can be derived from laboratory and field experiments or by measuring these vital rates in populations occupying different habitats. With appropriate information on the effect of habitats on these vital rates, such a model can be used to estimate the population's responses to likely or projected habitat change. Studies that use this approach often have identified early mortality as having a higher impact on a stock's productivity than fishing mortality (Greene and Beechie, 2004; Levin and Stunz, 2005), and hence lend support for integration into stock assessment models. Existing stock assessment modeling environments (e.g. SS) already can include age-, stage-, and space-specific variation in natural mortality, and thereby allow for the complexity demanded by a stage-based matrix approach.

This approach could work for those species that have strong affinities to habitat, occupy geographically well-defined habitats during large portions of their life cycle, and can be sampled in their habitats in a relatively straightforward manner. As such, these models may be more appropriate for short-lived species in coastal habitats where it is relatively easy to obtain estimates of habitat-specific abundance. Conversely, these models may be difficult to apply to long-lived species that are less tied to specific habitats during their entire life cycle, and to deepwater species whose abundance across habitats is difficult to assess.

Habitats and Stock-recruit Functions: Populations cannot increase in size indefinitely. Limited resources, such as food or shelter from predators, control population size. This limitation results in a habitat-specific carrying capacity that constrains a population's maximum productivity. The limitation on population growth usually is inversely related to population size and is referred to as density dependence. Density dependence can occur during any part of an animal's life cycle and theoretically can be examined from the relationship between abundance of the adults (the stock) and the abundance of some life stage in a subsequent cohort (the recruits). Stock assessments often reflect this assumption by incorporating stock-recruit functions like Ricker and Beverton-Holt relationships (Table 1), but these often are not linked conceptually to the availability of habitat and often do not recognize relationships at multiple life stages.

In their seminal paper, Beverton and Holt (1957) recognized the importance of density dependence at different life stages, and formulated a relationship that summed across habitat- or life-stage-specific stock-recruit relationships to increase the utility of the function. Subsequently, Mousalli and Hilborn (1996) reformulated the Beverton-Holt function to reflect multiple life stages. More complex models using this reformulation (Greene and Beechie, 2004; Scheuerell et al., 2006) provide ways to predict the influence of different habitats on fish populations. In the absence of data on survival rates, abundance or density estimates obtained for different life stages might be used to generate simple life-stage-specific stock-recruit curves and thereby provide a starting point for estimating habitat-specific productivity and capacity. Integrating such curves across life stages or among different habitat types could help reduce parameter uncertainty, which is usually very high in these models.

In addition, temporal fluctuations in habitat may help explain the variation that exists around these relationships. For example, in the west coast sablefish stock assessment, sea surface height (SSH) and two zooplankton anomalies were included as co-variates for recruitment deviations from the fitted stock-recruitment relationship (Schirripa, 2007). Recruitment deviations strongly correlated with all three indices, particularly with SSH. This example points to the need for models that can include temporally dependent habitat data to inform observations for fish stocks. Recent advances in stock assessment models, such as SS, could readily incorporate such variation.

Habitats, Movement, and Spatial Variation: Habitat availability and productivity vary geographically. Spatially explicit models and associated habitat data, therefore, hold promise to better understand abundance and productivity of stocks at the large spatial scales on which fisheries often are managed. With a few exceptions, many of these spatially explicit models currently are of heuristic value only (i.e. they provide insight on the potential influence of spatial variation on stock attributes), partly due to the large amount of required data. In addition to area-specific estimates of survival or fecundity, spatially explicit models require information on dispersal patterns of the species (i.e. movements among habitats). From a more practical standpoint, the increase in the spatial resolution of surveys over time may hinder comparisons among current and older periods. For these reasons, stock assessments have usually ignored spatial heterogeneity.

However, as noted by Field et al. (2006), the increasing use of MPA's for management of LMR's creates important spatial structure relevant to the demographic characteristics of the stock. Similar arguments apply to some habitat types (e.g. untrawlable habitats; Zimmerman, 2003). Consequently, stock assessments that integrate habitat-specific spatial information stand to improve accuracy in estimates of abundance.

The development of models like SS (Table 1), which can specifically incorporate spatial variability (Methot, 2009), makes habitat-informed stock assessments feasible. The challenge is to populate spatially explicit models with data that can reduce uncertainty of the assessment. This challenge is two-fold because the models require: 1) data on each spatial element; and 2) rules for linking spatial elements (e.g. movement matrices). While the first issue primarily depends on the extent of habitat observations, the second issue deserves more attention and could serve as a starting point for future research. Habitat-patch-specific information is not obtainable for most species, but general habitat classes, their relative availability, and how they affect demography may be sufficient to improve stock assessments. Likewise, certain rules-of-thumb (e.g. abundance or residence time is proportional to independently assessed habitat quality; Fretwell, 1972) may simplify incorporation of habitat variation and also reduce the uncertainty of the stock assessment. For some stocks, such rules-of-thumb might be sufficient to overcome uncertainty in movement rates among habitats.

For highly migratory species (HMS) such as tunas and billfishes, tagging efforts can explicitly inform movement rules in pelagic habitats. For example, pop-up tags that transmit high-resolution data via satellite have enabled scientists to describe pelagic habitat for Atlantic billfishes (Hoolihan et al., 2009). Further, chemical fingerprinting of fish tissues and otoliths have been used to understand the migratory patterns of Atlantic bluefin tuna (Dickhut et al., 2009). Defining habitat for HMS is an important challenge, particularly as the United States seeks the strongest possible management to conserve Atlantic bluefin tuna. Tagging efforts coupled with habitat assessments can elucidate the influence of habitat heterogeneity on age- or stage-specific movements of these and many other species.

Capability of Stock Assessment Models to Include Habitat Data

The inability of stock assessment scientists to incorporate habitat data directly into assessment models potentially could be a significant impediment to advancing to SAIP Tier 3 stock assessments. In the questionnaire developed by the HAIP Team, NMFS scientists having stock assessment and population biology expertise (n = 46) were asked to rate the potential of stock assessment models to accommodate specific types of habitat data. Respondents could rate these types of data as: 1) requiring new stock assessment models; 2) requiring some modification of existing models; or 3) not necessitating changes to models because existing models would readily accommodate the habitat data.

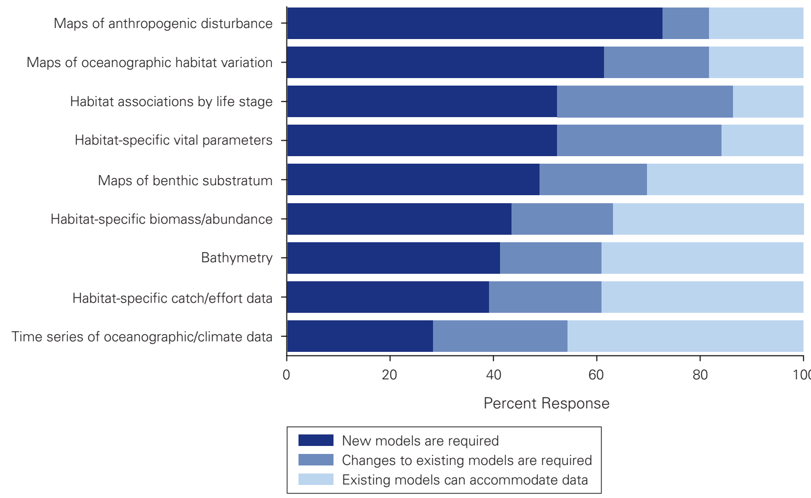


Figure 9

The capability of stock assessment models to accommodate different types of habitat data. Bars indicate the percent frequency of questionnaire respondents (n = 46) who thought: 1) new models are required to integrate each type of habitat data; 2) changes to existing models are sufficient; or 3) existing models can accommodate the specific type of data.

Respondents indicated that some types of habitat data would be more difficult to integrate into stock assessment models than others (Figure 9). In particular, a majority of scientists indicated that habitat-specific vital parameters and information on habitat associations by life stage would require modified or new models. Most scientists also responded that incorporation of maps of dynamic oceanographic features (e.g. chemical, temperature, or current variation) and of anthropogenic impacts would require modification or creation of new models. In contrast, respondents generally reported that time series of oceanographic and climate variation, and to a lesser extent bathymetry and habitat-specific catch, effort, and biomass data, could be incorporated with little or no modification to existing models.

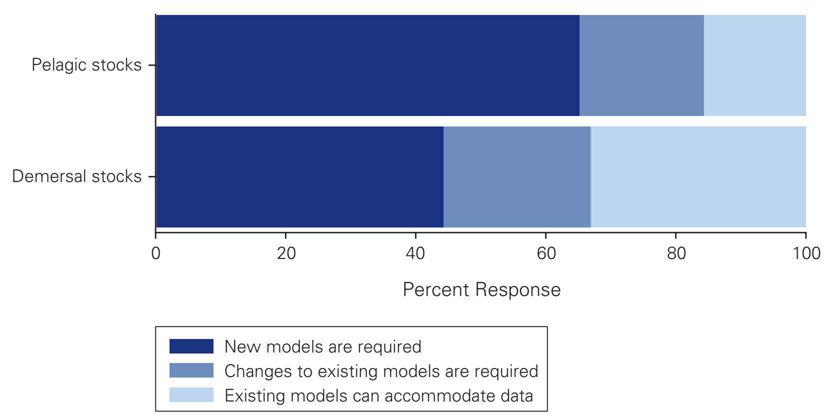


Figure 10

The capability of stock assessment models to accommodate any type of habitat data, by responses from stock assessment scientists who study demersal and pelagic stocks. Bars indicate the percent frequency of questionnaire respondents who thought: 1) new models are required to integrate each type of habitat data; 2) changes to existing models are sufficient; or 3) existing models can accommodate the data.

These perceptions were clearly influenced by both the species studied and the geographic region in which the scientist worked. Scientists that studied demersal stocks were more optimistic of the capability of models to integrate habitat data than scientists working with pelagic stocks (Figure 10). Interestingly, scientists from the NWFSC were more optimistic about the capability of models to incorporate habitat data at some level than scientists from any other region, and scientists from the NEFSC were more skeptical (Figure 11). This pattern could be a consequence of the species assessed by the respondents and the types of stock assessment models used by scientists in different regions.

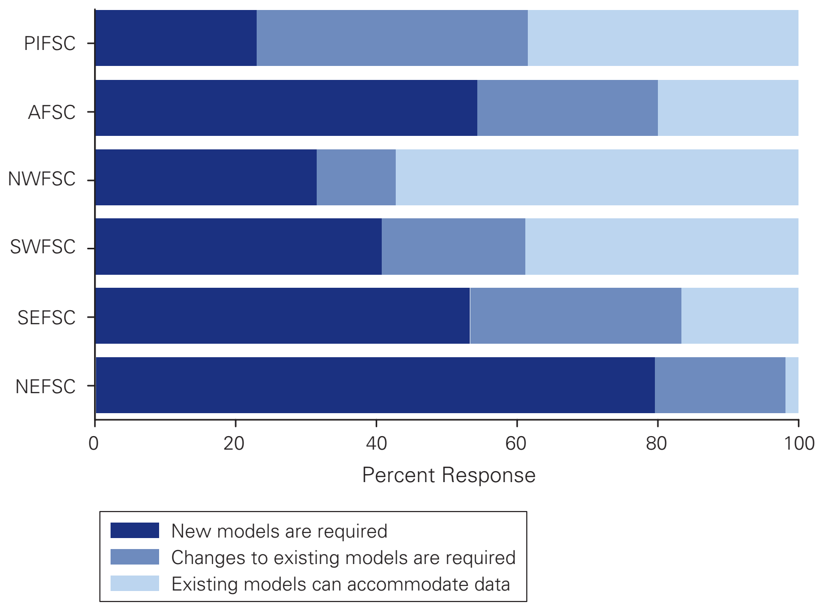


Figure 11

The capability of stock assessment models to accommodate any type of habitat data, by responses of stock assessment scientists from each NMFS Fisheries Science Center. Bars indicate the percent frequency of questionnaire respondents who thought: 1) new models are required to integrate each type of habitat data; 2) changes to existing models are sufficient; or 3) existing models can accommodate the data.

In addition to querying opinions of stock assessors, the HAIP Team reviewed some of the core tools in the Stock Assessment toolbox and found elements in the models that could incorporate habitat data (Table 1). Several models have entry points by which habitat data could be integrated, including habitat-specific vital rates (i.e. natural mortality and growth), stock-recruit parameters, and movement formulations. In fact, SS provides all such capabilities and all parameters can exhibit spatio-temporal variation. The greatest challenges to be met are the lack of useful habitat data and the synthesis of the observations. Currently, data often are not collected or integrated in a habitat-specific manner and, until such efforts are made, advances in linking habitat and stock assessments will proceed very slowly.

Habitats, Integrated Ecosystem Assessments, and Coastal and Marine Spatial Planning

One of NOAA's goals is to "protect, restore, and manage the use of coastal and ocean resources through an ecosystem approach to management" (NOAA, 2008). EBFM requires a comprehensive framework for making decisions about LMRs. In contrast to single-species or single-issue management, EBFM considers a wider range of relevant ecological, environmental, and human factors bearing on societal choices regarding resource use. In this context, EBFM is adaptive, is geographically specified, takes account of ecosystem knowledge and uncertainties, considers multiple external influences, and strives to balance diverse societal objectives (Murawski and Matlock, 2006).

Ecosystem-based fisheries management requires managers to consider all interactions that a fish stock has with predators, competitors, and prey species; the effects of weather and climate on fisheries biology and ecology; the complex interactions between fishes and their habitat; and the effects of fishing on fish stocks and their habitat (EPAP, 1999). While ocean and coastal resource managers recognize the ultimate use of an EBFM approach, implementation for fisheries, habitat, and coastal watersheds presents substantial challenges. Little practical experience is available to assist managers in achieving EBFM (Levin et al., 2009). Likewise, limited ecosystem data are available to derive decision support tools that facilitate the selection and testing of alternatives to EBFM. NOAA is in the process of establishing the scientific underpinning for EBFM of ocean and coastal LMR's so that complex management actions are based on comprehensive, cumulative, and reliable science (Murawski and Matlock, 2006).

IEA's are an emerging tool for NMFS to use in meeting EBFM objectives for U.S. coastal waters. An IEA is the synthesis and quantitative analysis of information on ecological and human processes relevant to a specified set of EBFM objectives (Levin et al., 2009). IEA's combine biological, physical, chemical, and geologic data and socioeconomic information to quantitatively assess a range of possible management objectives that could affect ecosystems (Levin et al., 2009). While this approach is still in its infancy, four promising IEA's (Chesapeake Bay, the Gulf of Mexico, the California Current, and Puget Sound) are under development.

Components of IEA	Role of Habitat Assessments
Identify goals of EBFM and threats to achieving those goals	Identification of goals for, and threats to, fisheries or habitat
Develop ecosystem indicators and targets	Determination of the use of habitat observations in ecosystem monitoring
Risk analysis and assessment of ecosystem status	Determination of uncertainty associated with habitat impacts and habitat observations
Management strategy evaluation	Construction of spatially explicit ecosystem models that incorporate habitat heterogeneity
Monitoring indicators and management effectiveness	Evaluation of multiple habitat assessments over time

Table 2

The role of habitat assessments in an integrated ecosystem assessment (components modified from Levin et al., 2009).

Habitat science and habitat assessments are at the core of an IEA (Table 2) and, by extension, EBFM. Habitat assessments furnish information on the structure and function of the ecosystem in which fishing activities occur, thereby increasing awareness of both the effects of management decisions on the ecosystem and the effects of other components of the ecosystem on fisheries. The abundance, spatial arrangement, and quality of habitats affect the integrity of ecological systems and critical population metrics, such as encounter rates between predators and prey, availability of refuges from predation, vital rates, productivity, incidence of disease, and many other processes that potentially influence the sustainable yield of exploited populations (Breitburg and Houde, 2006; Walters and Martell, 2004). As such, the link between habitat science and IEA's deserves further investigation and refinement.

IEA's comprise a five-stage process for EBFM: 1) scoping; 2) developing ecosystem indicators; 3) risk analysis and assessment of ecosystem status; 4) management strategy evaluation; and 5) monitoring (Table 2). There are several entry points through which habitat assessments can improve IEA's. During the scoping stage, habitat assessments can help in identifying threats to EBFM goals in at least two ways. First, EBFM goals can include fisheries sustainability, which can be influenced by impacts to habitats and associated population dynamic functions. Second, EBFM goals can include the importance of habitat integrity in and of itself. In this case, habitat assessments can support EBFM even in the absence of certainty in the causal mechanisms that link habitat impacts to stock production.

Once habitat integrity is incorporated into EBFM goals, indicators of stock or habitat status need to be developed. Observations of habitat processes, distribution, and impacts should be evaluated in the context of other ecosystem indicators (e.g. surveys of species abundance, socioeconomic indicators) in order to develop realistic management targets related to these indicators. Scientists often rely on driver-pressure-state-impact-response (DPSIR) conceptual models to help clarify which indicators will be most useful (Niemeijer and de Groot, 2008). Some of the most successful DPSIR models have well-developed habitat modules in which anthropogenic pressures affecting habitat are explicitly incorporated, changes in habitat state are assumed, and both habitat and species impacts are identified. Successful conceptual modeling supports the risk analysis stage of an IEA, in which ecosystem targets are examined in light of uncertainties in estimating current and historic habitat characteristics and level of impact.

Habitat assessments can be incorporated into the fourth stage of an IEA (i.e. evaluating management strategies) using spatially explicit ecosystem models. The Atlantis model (Figure 12; Fulton et al., 2005) is one successful example, whereby users specify habitat "boxes" that correspond to three-dimensional units of analysis. While habitat composition can be varied within the boxes, the total number of boxes in such a model is a compromise among conflicting issues, including realistic match to number of distinct habitats and their boundaries; data availability within each model cell; and computation speed. Overcoming such challenges is an emerging area of research in habitat science. In the final ecosystem monitoring stage of an IEA, scientists verify predictions and determine the effectiveness of management. Habitat assessments are reevaluated in light of new data. This last step closes the feedback loop necessary for effective EBFM.

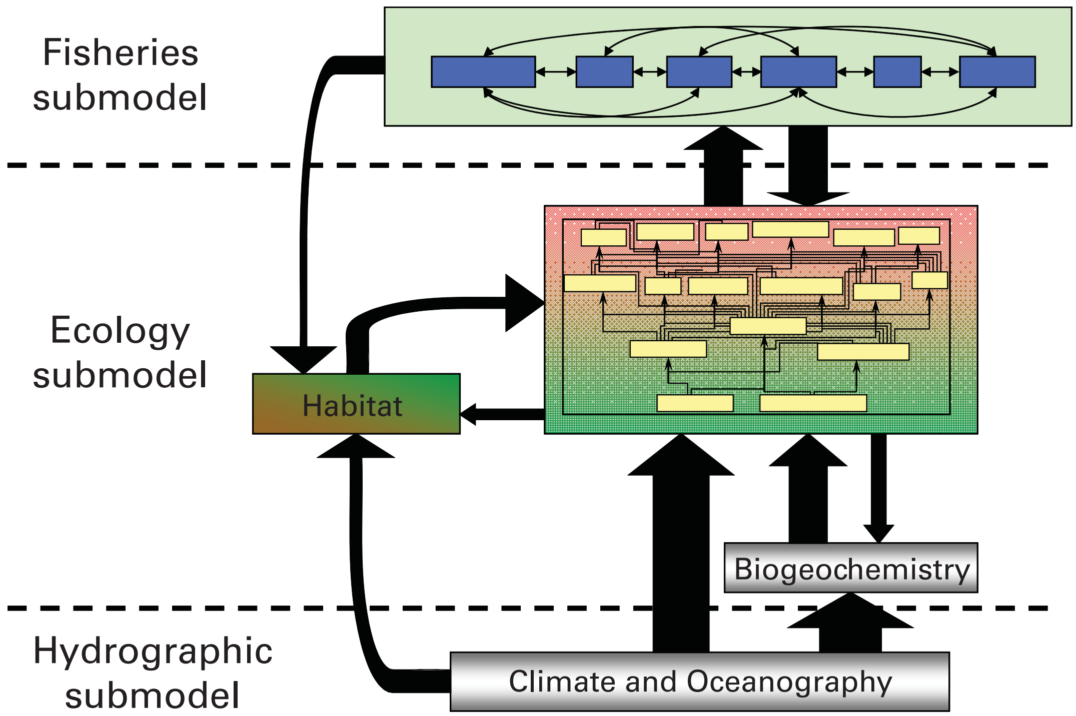


Figure 12
Schematic of the Atlantis ecosystem model, which simulates oceanography, ecology (including habitat effects), and fishing (from Brand et al., 2007).

NMFS has become an active participant in CMSP, an effort to allocate compatible human uses of the oceans while sustaining important ecological, socio-economic, and cultural functions for the future (NOAA Ecosystem Goal Team et al., 2009). CMSP is a comprehensive, ecosystem-based process that involves many components of NOAA as well as numerous other Federal agencies and stakeholders. It is intended to reduce impacts of human activities in ecologically sensitive areas and conflicts among incompatible activities, while maintaining ecosystem services.

The Interagency Ocean Policy Task Force (2009a) has drafted an interim national policy "that ensures the protection, maintenance, and restoration of the health of the ocean, coastal, and Great Lakes ecosystems and resources...". The objectives for implementing this policy include ecosystem-based management, CMSP, and science-based regional ecosystem protection and restoration. The Task Force (2009b) is also currently developing a government-wide framework for CMSP. The concept underlying this effort is that the current sectoral allocation of ocean space will evolve into an ecosystem-based, adaptive management process in a manner similar to the transition from single-species fisheries management to EBFM and IEA's. The Framework describes benefits, governance, a phased process for implementation, and needs for scientific knowledge, data integration, research, management, and access to the CMSP information.

Many of NOAA's legal authorities, functions, and capabilities are relevant to CMSP. NOAA collects a wide range of spatial data on ocean resources, uses, and characteristics, develops and uses decision-support tools, and conducts spatial analyses of marine data to support regional planning and management. Habitat maps and information on the relationships between living marine resources and their habitats are major components of the information upon which effective CMSP will depend.

Many of NMFS' stewardship mandates result in regulation of marine areas, including designation of EFH and HAPC's for fishery species and Critical Habitat for ESA-listed species. These regulations can lead to restrictions in fishing and nonfishing activities for conservation purposes. Such regulations are based on habitat science and assessment. The NOAA Ecosystem Goal Team et al. (2009) identified CMSP functions, all of which are significantly linked to habitat science and assessment (Table 3).

Table 3

The contributions of NMFS habitat science and assessments to the various functions of coastal and marine spatial planning (NOAA Ecosystem Goal Team et al., 2009).

CMSP Functions	Contributions of NMFS Habitat Science and Assessments
Spatially explicit ecosystem information	NMFS generates, analyzes, and interprets data on important habitats, species, and ecological processes for designation of EFH and Critical Habitat of ESA-listed species and for development of fishery regulations
Spatially explicit assessment of ocean uses	Habitat assessments and maps of EFH, fishery regulations, and Critical Habitat
Decision support tools	NMFS generates, analyzes, and interprets data of fishery species and associated habitats
Interagency coordination	Federal agencies must consult on actions that potentially impact EFH and ESA-listed species
Policy framework	CMSP legislation and policies will be based on sound scientific principles to conserve habitats and ecosystem function and services

Section 4: Data for Habitat Assessments

At a Glance

- Habitat assessments require both collection and synthesis of multiple types of data at a variety of temporal and spatial resolutions.
- Research efforts to collect habitat data have been fragmented and limited, with our greatest success demonstrated by the physical characterization of habitats.
- A survey of NMFS scientists indicated that most habitat data occur at low resolution based on inadequate information.
- Primary challenges to the effective management of habitat data are: the multiplicity of data types and the large volume of imagery data; the lack of appropriate metadata and accessibility to research data; and the means to efficiently collect and process data and produce the required products.
- Habitat data collection efforts and data management initiatives should be coordinated across NOAA and its partners.
- NMFS data management systems and integration applications should be expanded, and the number of NMFS technical staff should be increased.

Habitat assessments require input data that vary not only on spatial and temporal scales of resolution, but also in complexity relative to the ecosystem processes being studied. The foundation of a habitat assessment requires information at increasing levels of understanding or resolution from three major categories: 1) habitat type and area (i.e. characterization and delineation of habitats); 2) ecological value of habitat (i.e. habitat-specific species abundance, growth, mortality, reproduction, and production) and the functional relationships within and among habitats; and 3) habitat status or condition (Figure 13). Critical to the synthesis of these three categories of habitat data are the levels of data integration and the frequency at which assessments are conducted to monitor habitat change. A habitat assessment includes all of these components.

While a variety of habitat data have been collected by NMFS and others, most of these data have been gathered for disparate, project-specific purposes and do not lend themselves to the type of integration and synthesis required for habitat assessment. Our ability to conduct habitat assessments will remain hampered until systematic habitat research efforts are coordinated and implemented at appropriate spatial and temporal scales using methodologies that facilitate integration of the diverse physical, biological, and socioeconomic data needed for these assessments. Enterprise data management initiatives, such as NOAA's Integrated Ocean Observing System (IOOS) and a system being developed by NMFS F/ST, will facilitate data management and integration efforts in the future. These systems, however, are still relatively undeveloped, especially as relevant to habitat and life-cycle data for fishery species.

Characterization and Delineation of Habitats

Marine habitats are characterized and delineated using physical, chemical, and biological data. These data are collected using a variety of survey instruments and methods, collated, analyzed, and translated into maps for use in habitat or stock assessments. Due to limitations of the surveys, data, and analyses, most habitat maps are usually not explicit and often are derived from a reasonable environmental proxy (e.g. depth, grain size, rugosity, and water temperature; Figure 14). The acceptability and usability of habitat maps based on such proxies depend on the resolution and quality of the sampling, the method of inferential interpolation, the classification analyses, and the degree to which other important functional characteristics (e.g. properties

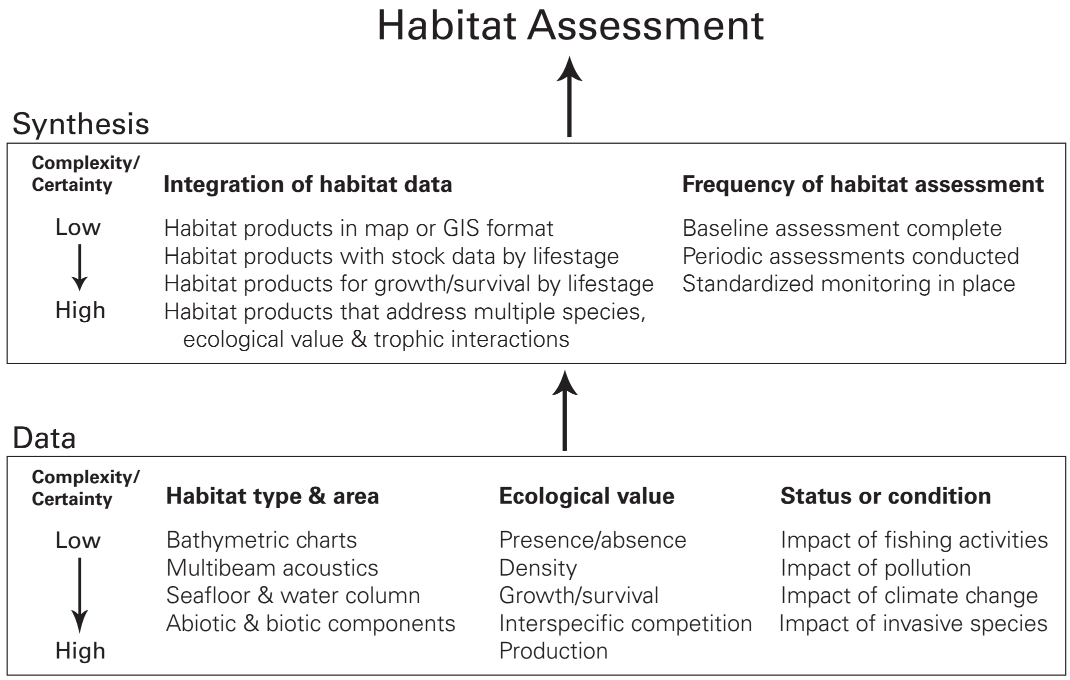


Figure 13
Flow of information from the Data Block to the Synthesis Block, which together produce a habitat assessment.

most critical to distribution, spawning, growth, and mortality of fishery species) of the habitat have been delineated. Appropriate spatial statistics, habitat classification schemes, and mapping conventions, therefore, are essential to reduce uncertainty and facilitate the explanation and mapping of functional relationships.

Data types that are commonly used to characterize habitats are listed in Section 2 (p. 13). Scientists have imperfectly, but often usefully, organized habitat characteristics into hierarchical classification schemes, several of which have been proposed for U.S. coastal and ocean systems. For example, NOAA's Coastal and Marine Ecological Classification Standard (Madden et al., 2009) has three distinct components (i.e. benthic, water column, and geoform) that together provide a framework and standard terminology for describing marine and coastal habitats. Greene et al. (2007) emphasize the importance of schemes with flexibility to meet the needs of various users both within and across regions.

The absence of consensus on habitat classification schemes has not impeded habitat mapping. In fact, there has been a rapid increase in the interest of mapping marine benthic habitats over the past two decades (e.g. Noji et al., 2004; Todd and Greene, 2007). While large amounts of bathymetric and geomorphological data have been collected (for instance, see Brown and Thomas, 2008), these data are most suitable for habitat delineation and assessments when collected and verified (groundtruthed) specifically for such purposes. Recent efforts to increase collection efficiency using ROV's, AUV's, and unmanned aircraft systems, coupled with improvements to data collection instrumentation (e.g. synthetic aperture sonar, laser line scan imaging, and high-resolution video imaging), could provide useful data on multiple scales (centimeters to kilometers) to improve habitat delineation. Most of these emerging technologies are relatively expensive at present, require specially trained operators, and create significant challenges in data processing and storage. Partnerships among multiple users, such as that recently forged in NOAA's Integrated Ocean and Coastal Mapping Program (IOCM) (Appendix 6), are critical to realize the full benefits of these technologies for practical resource management.

Mapping pelagic ecosystems also is fundamental to habitat assessments for many managed species. Pelagic habitats occur in a three-dimensional dynamic fluid medium where vertical and horizontal boundaries of the system are far less static with regard to temporal and spatial scales than are the boundaries of a benthic system. The oceanographic disciplines (i.e. physical, chemical, geological, and biological) provide a description of the properties of this fluid environment (e.g. temperature, salinity, chlo-

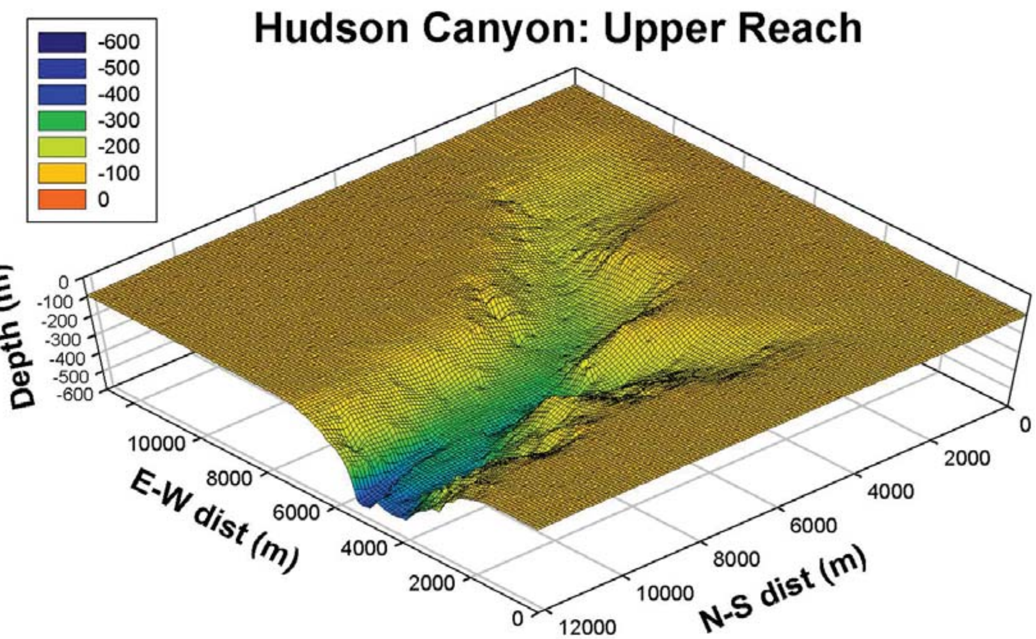


Figure 14
Example of a habitat map of the Hudson River Canyon off New York and New Jersey, based on depth as an environmental proxy. Map courtesy of Vincent Guida, NEFSC.

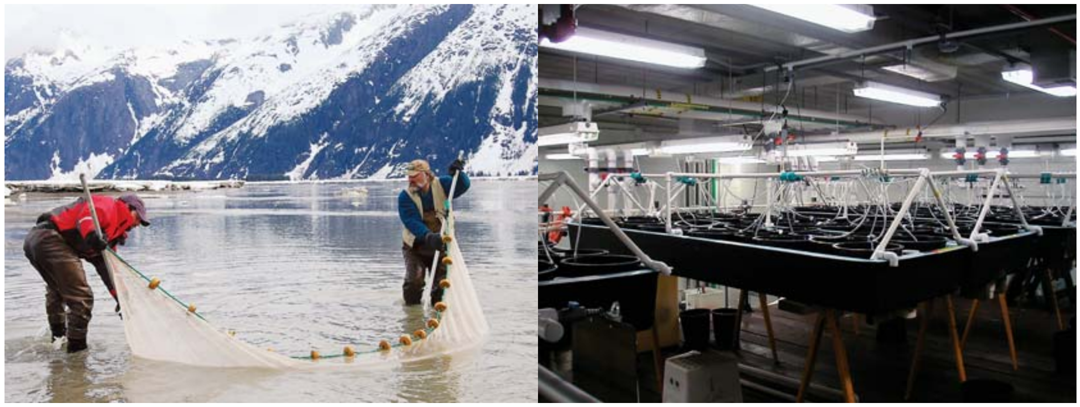
rophyll), the currents, and water masses. Data at the sea surface are collected on a regional scale by a variety of satellite-borne sensors. Moored and drifting buoys collect and transmit temperature, salinity, pressure, and current profiles at multiple ocean depths. Research vessels also are used to collect environmental data, as well as associated biological samples, at specific stations. Archival and pop-up tags attached to fishes, turtles, and mammals collect data on geo-location, light, temperature, and depth that are used to model both pelagic habitats and the organism's movement over time.

Habitats are delineated for management purposes even in the absence of meaningful environmental and biological data. Bathymetric data often have been used to define management boundaries for EFH, HAPC, MPA's, and other political or management zones (National Marine Protected Areas Center, 2008). In other cases, noticeable landmarks, treaty agreements (e.g. EEZ's), or relatively arbitrary distance units are used to delineate habitat boundaries. These political boundaries usually are determined without regard to habitat types or ecological function. Coastlines, population maps, hydrologic and hydrographic maps, draft Environmental Impact Statement alternatives, socioeconomic census data, digital elevation models, and sediment maps also could influence habitat delineation.

Ecological Value of Habitats

Information on the distribution, abundance, and life history of managed stocks is commonly based on fishery-dependent sampling of catch and on fishery-independent surveys using various fishing gears. Fishery-independent trawl surveys are among the highest quality data sets in NMFS, generally being conducted under controlled conditions using standardized sampling protocols and gear. These data often are collected as individual samples that integrate over broad (kilometer) spatial scales. Little or no concomitant habitat information is collected during these surveys, with the exception of broad-scale, low-resolution data on depth, location, and perhaps temperature that are integrated over the entire sample and used to document a range of biogeographical and depth patterns of associated species (Williams and Ralston, 2002).

Various methods, ranging from field observations to laboratory experiments, have been used to quantify habitat value. Visual survey techniques using scuba and various types of underwater vehicles, combined with large-scale remote acoustic surveys, have been used successfully to quantify habitat associations for some species at the spatial scales of fisheries (Section 3, p. 19). A number of collaborative teams of fisheries biologists, marine ecologists, and marine geologists have advanced this approach



Both field observations and laboratory experiments are important to quantify habitat value.

Left: Doris Alcorn, AFSC; right: NEFSC.

to the level of a recognized discipline, as illustrated by two recently published volumes on mapping seafloor habitats and fish associations (Reynolds and Greene, 2008; Todd and Greene, 2007). At much smaller spatial scales, laboratory, mesocosm, and field caging studies also are used to document interactions between fishes and biotic and abiotic features of habitats, and measure habitat use under differing structural complexity and predation pressure. These types of studies can provide information on vital rates such as mortality and growth for certain life stages under differing environmental conditions.

Habitat is the context in which species interact. Habitat-specific life history data and information on the interdependence of fish stocks, including both physical and biological relationships (e.g. food webs or shared habitats), are relatively sparse. Stomach content analyses, consumption rates, food preference studies, nutritional analyses, stable-isotope analyses, otolith microchemistry, forage fish abundance measures, predator-prey dynamics, spatial differences in stock distribution as measured by catch and DNA analysis, home-range field observations, and analyses of bycatch are used to understand the functional relationships among ecosystem components. These efforts, although not prolific, will be key in developing food web models for IEAs (Link et al., 2008b). Research on interactions at multiple trophic levels is even less well developed. While stock assessment models are being developed to include these interactions and models of ecosystem-wide food webs are being calibrated with such information, the data needed to advance these investigations are substantial. Habitat information will be essential in understanding the significance of predator-prey interactions.

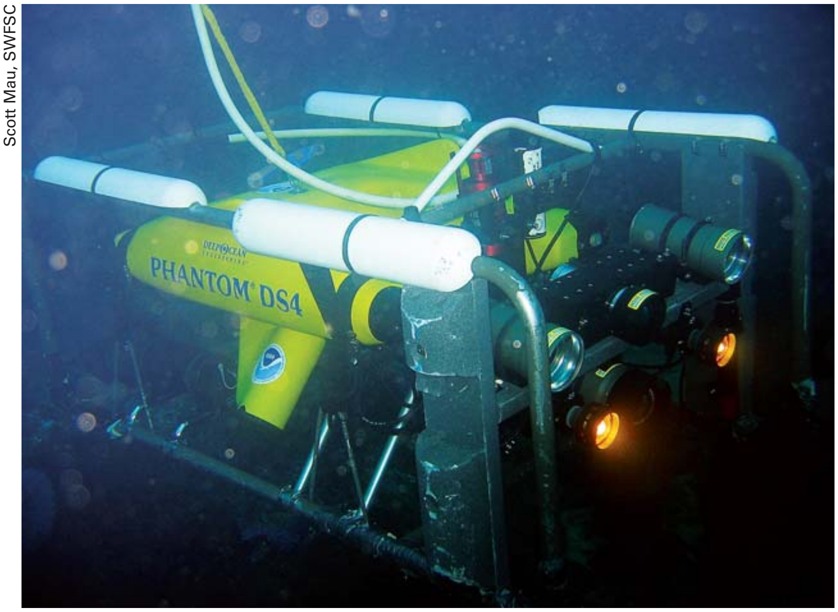
Thus far, however, we have achieved more success in mapping physical features of potential habitats (e.g. distribution of rocky seafloor, kelp beds, and upwelling plumes) than in conducting the biological sampling necessary to define and delineate critical ecological relationships specific to those habitats. The functional relationships between species and habitats have yet to be elucidated largely because of the difficulty in obtaining datasets at relevant spatial and temporal scales commensurate with distribution and abundance of important life stages. The identification of habitat properties critical to growth and survival remains a large gap, particularly in our understanding of sensitive life stages and of nontargeted species.

Status or Condition of Habitats

The changing status (or condition) of habitats is another challenging aspect of a habitat assessment. Changes that result from indirect influences at the community level or across the wider ecosystem are least understood and can influence the habitat's ecological relevance. Physical, biological, and chemical degradation can alter the ecological services provided by habitats, and can be an important consideration in maintenance of the biochemical balance of the ecosystem and subsequent responses of fishery stocks. Physical impacts, such as disturbance to seafloor communities from bottom-contact fishing gear (Barnes and Thomas, 2005) or effects of sedimentation from coastal runoff, can be identified and often quantified with direct or remote observations. Changes to biodiversity associated with introduced and invasive species can be difficult to recognize, and chemical and other water quality impacts to the ecological balance may be the hardest to identify and measure for many reasons. Nonpoint source pollution is often ubiquitous, our perception of climate change can be that it is gradual or episodic, and physiological impacts may only be discernible over long monitoring periods. Furthermore, little or no baseline information is available on community structure in most ecosystems that we manage.

Visual methods to monitor the status or condition of benthic habitats include scuba, manned submersibles, towed and drop cameras, laser line scanners, AUV's, ROV's, and aerial/satellite sensors. Data products from these tools often are in the form of video or other imagery. Interpretation of such data requires substantial funding and trained personnel (Somerton and Gledhill, 2005), and NMFS programs that characterize biological components of benthic habitats often rely opportunistically on external funding and rarely include long-term monitoring.

Scott Mau, SWFSC



Visual methods using underwater tools such as the Phantom ROV are important in monitoring the status and condition of habitats, but can present challenges in terms of data interpretation and storage.

NMFS Science Centers and Regional Offices operate limited water quality monitoring programs that collect chemical, physical, and biological data that may reflect habitat condition. These programs operate primarily in estuarine and near-shore environments, which can be subject to substantial anthropogenic impacts; these programs are rarely spatially or temporally adequate for habitat assessments. NOAA's National Ocean Service (NOS) and National Centers for Coastal Ocean Science (NCCOS) operate the National Status and Trends Program, the National Estuarine Eutrophication Assessment Program, the Coral Reef Ecosystem Monitoring Program, the Monitoring and Event Response for Harmful Algal Blooms Research Program, and the National Marine Sanctuaries habitat monitoring programs. Water quality monitoring programs also are conducted by other government entities such as U.S. Geological Survey (USGS), Environmental Protection Agency, and the coastal states, and usually are focused on rivers, estuaries, and coastal beaches. NOAA's Office of Oceanic and Atmospheric Research (OAR) and NCCOS conduct limited monitoring programs on invasive species, generally through state and nonprofit partners.

Monitoring the impacts of climate change on marine habitats will be especially demanding. Changes to sea level, sea temperature, salinity, carbonate chemistry, ocean currents, ocean structure, wave dynamics, storm frequency and intensity, and rainfall all will have considerable effects on habitat distribution over various time scales. NOS and NOAA's National Environmental Satellite, Data, and Information Service currently use a combination of satellite and buoy measurements to assess the impacts of climate change on a limited number of habitats in coastal and ocean ecosystems.

Even when considered together, these programs do not constitute a comprehensive, coordinated national enterprise to effectively evaluate and monitor marine habitats. Funding constraints limit the number and diversity of sampling sites, as well as the frequency of sampling. The absence of a national program precludes assessments of water quality and biological condition of coastal and marine habitats (COP, 2004).

Management of Habitat Data

Even cursory habitat delineations and assessments demand a variety of data; systematic efforts to achieve acceptable levels of data quality and to manage these data are limited. In addition, data integration remains a substantial challenge regardless of the collection and accessibility of appropriate data. Three of the most vexing challenges to the effective management of habitat data are: 1) the multiplicity of data quality and types, definitions, and resolutions, and the large volume of imagery data; 2) the general lack of appropriate metadata, base maps, and geospatial frameworks; and 3) the limited ability to collect, store, access, integrate, analyze, and distribute data in a consistent, coherent, and efficient way. While some progress has been made in developing data management and integration systems for habitat science at some Science Centers, these are relatively isolated efforts. Many of the Science Centers and their partners have engaged in the opportunistic collection of specific types of habitat data, while few have had the necessary resources to pursue systematic collection and analysis of such data for habitat delineation and assessment. Data are collected on various temporal and spatial scales with a variety of instruments and protocols, aggregated and analyzed with multiple methodologies and classification schemes, and archived (often without appropriate metadata) in a perplexing array of information systems and data formats. All of these deficiencies in data quality control, compatibility, and analytical methods hamper the effective and efficient integration and distribution of NMFS' habitat data. Consideration of NOAA's IOOS data management standards and protocols could alleviate some of the problems associated with many disparate physical data sets, but the management and delivery of NMFS' biological data present significant challenges.

Adequacy of Habitat Data

As noted earlier (Figure 13, p. 38), the foundation of a habitat assessment requires data from three major categories: 1) habitat type and area; 2) ecological value of habitat; and 3) habitat status or condition. The HAIP Team polled 133 NMFS habitat and ecosystem scientists, population/stock assessment scientists, and resource managers to assist in identifying the level of complexity and certainty in data that is currently available for each of these categories. Our descriptions of the types of available data, while not mutually exclusive, were designed to represent a series of increasing complexity and certainty (from low to high) in our comprehension of habitat data. Our survey was not intended to capture all dimensions in habitat data, but instead serves as a measure of habitat data currently available to support habitat and stock assessment goals and emerging issues in ecosystem management. Respondents were asked to score the adequacy of each type of data availability as having: 1) no information; 2) insufficient information; 3) or adequate information. Progress is needed in each of the three data categories to develop successful habitat assessments, and thus there should be concurrent efforts to advance our level of understanding in each category.

Data on type and area of habitat (listed from low to high complexity and/or certainty)

- Bathymetric charts or other sources of information on water depth, which are used with field sampling and observations to infer the distribution of managed species.
- High resolution, multibeam acoustic survey data (e.g. acoustic backscatter data to discern hard and soft areas of the seafloor) that improve our characterization of seafloor substrata are used to infer distribution of managed species.
- Water-mass features (e.g. currents, eddies, vertical structure of temperature) associated with topography (e.g. seamounts, island masses, banks, canyons) are identified as influential attributes of habitat.
- Surveys of habitat, including abiotic components (e.g. substratum type, hydrographic variables) and associated biotic components (e.g. kelp, coral, sea grass, sponges), result in an improved understanding of community and ecosystem structure and function.

Data on ecological value of habitat (listed from low to high complexity and/or certainty)

- The distribution of the managed stock is predictable based on presence/absence by habitat types (depth, temperature, or other attributes of habitat).
- Habitat-specific abundance (e.g. density, biomass, CPUE) of the stock is known.
- Habitat-specific vital parameters such as growth and mortality are known.
- Direct and indirect roles of habitat as prey, shelter, and inter-specific competition for managed stocks and

other ecosystem taxa have been assessed by survey or experimental methodologies.
- Projections of production are linked to the quality and availability of habitat types.

Data on habitat status or condition (listed from low to high complexity and/or certainty)
- The degree that habitat is altered from trawling, longlines, trapping, and other fishing activities is known. Note: As regulation of fishing is the mandate of NMFS, it is possible to address fishing impacts more directly than the following issues.
- Information is available on the degree that habitat is altered by point and nonpoint source pollution.
- Information is available on the rates that climate is altering habitat (e.g. change in temperature, sea level, salinity, pH, etc.) for managed stocks and the ecosystem.
- The degree to which invasive species alter habitat form and function is known, as well as the consequences to the managed stock and ecosystem.

Most survey respondents divided their answers between the choices of none and insufficient to describe the state of knowledge for the three data categories (Figure 15). Some survey respondents indicated that they chose insufficient over the none category because some very basic information was available even though the amount often was extremely limited. A clear minority of respondents indicated that there were adequate data in each of the data categories, and the proportion of these respondents diminished with increasing levels of data complexity. Patterns of response were consistent for both the early life stages and harvest stages of managed taxa, with uncertainty generally larger in early life stages. Insufficient was the dominant response for the type-and-area data category, with only the lowest level (bathymetric charts) given an equal proportion of responses as adequate. For the ecological value data category, insufficient was the dominant response and the proportion of none responses increased at higher data levels. The habitat status data category was dominated by the insufficient response, except for data concerning invasive species where none was the most frequent response.

The overall response of the survey indicates an overwhelming inadequacy of habitat data to support even rudimentary habitat assessments. These patterns persisted when the data were evaluated in the context of pelagic versus demersal stocks and by the noted discipline of the respondents (e.g. stock assessors, habitat scientists, and managers).

Adequacy of the Synthesis of Habitat Data

Critical to the synthesis of the three categories of habitat data discussed above (i.e. type and area; ecological value; and status or condition) are the levels of data integration and the frequency at which assessments are conducted to monitor change in habitat status or condition. The synthesis element of a habitat assessment will vary with each application.

Integration of habitat data (listed from low to high complexity and/or certainty)
- Habitat products are in map or GIS format.
- Habitat products include data on stock abundance by life stage.
- Habitat products include growth and survival of stock by life stage.
- Habitat products include multiple species, ecological value, and trophic interactions.

Frequency of habitat assessment (listed from low to high complexity and/or certainty)
- Baseline assessments are available.
- Periodic assessments are being conducted.
- A plan for standardized long-term monitoring is in place.

The majority of survey responses for adequacy of data integration and frequency of assessments were either none or insufficient

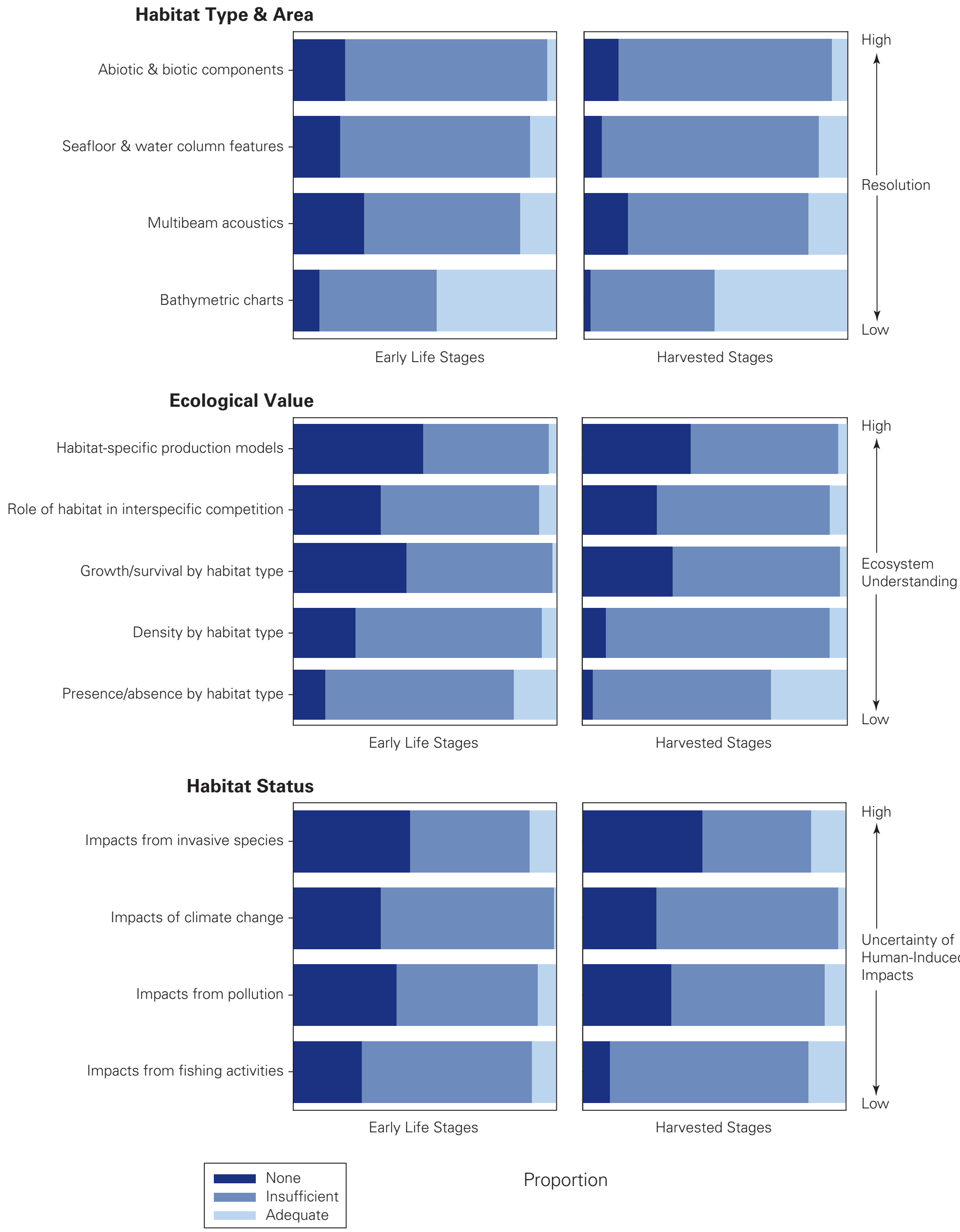


Figure 15

Proportion of scores from respondents on the adequacy of information in three habitat data categories (type and area; ecological value; and status) by life stage (early vs. harvested) of FSSI stocks.

(Figure 16). Very few respondents indicated that either integration of habitat data or the frequency of habitat assessment was being conducted at an adequate level. The proportion of the none response notably increased with the level of data integration and assessment frequency for both the early life and harvest stages of taxa. Integration of habitat data with ecosystem considerations was completely absent. In summary, responses to the survey indicate very little synthesis of habitat data has been conducted, which is likely tied to the limited availability of data.

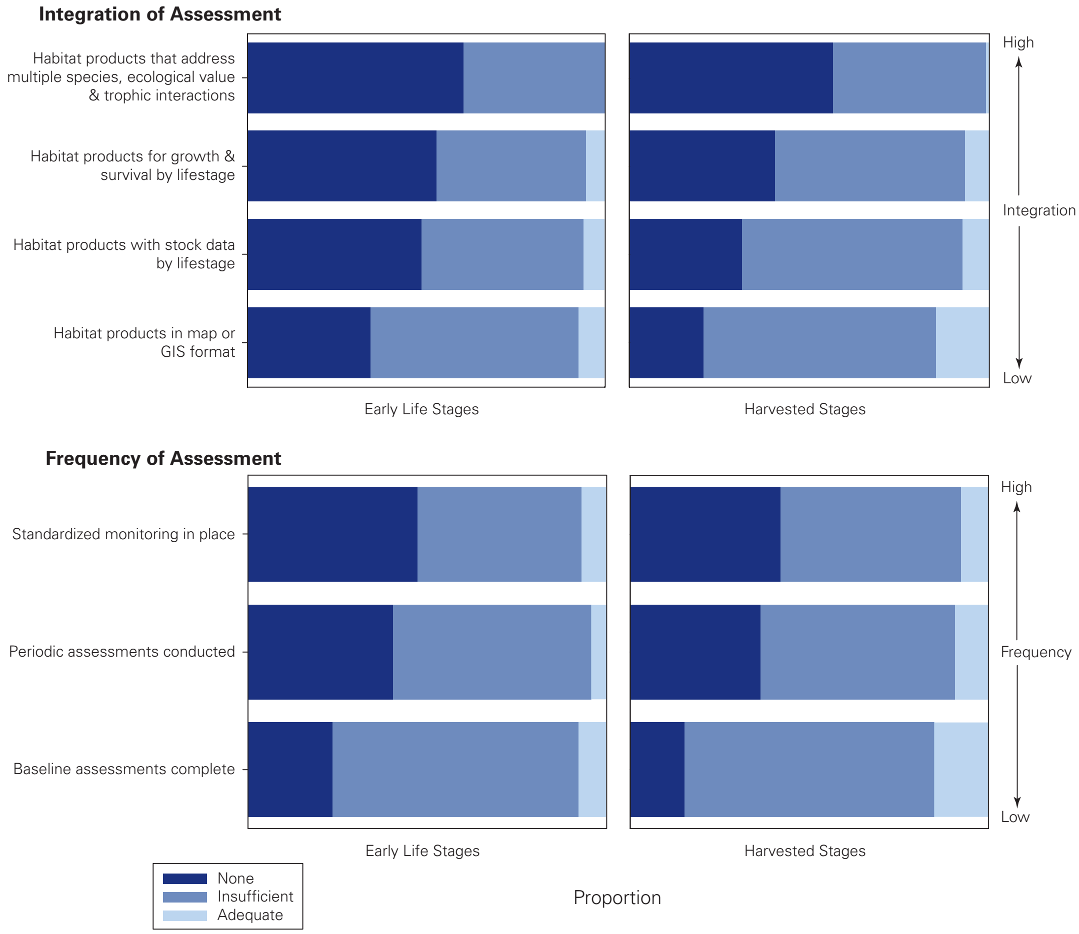


Figure 16
Proportion of scores from respondents on the adequacy of data integration and frequency of habitat assessments, by life stage (early vs. harvested) of FSSI stocks.

Adequacy of Staffing

Many demands are placed on habitat assessment scientists aside from the basic duties required to conduct habitat and ecosystem research. In fact, few scientists are actually dedicated to a single discipline; consequently a team of scientists with diverse skills typically carries out habitat research. Within a given year, an individual habitat assessment scientist may be expected to: 1) participate in fishery-independent surveys or other field work; 2) provide input on data collection objectives and protocols for observer programs and other fishery-dependent activities; 3) quality control data; 4) conduct habitat assessments; 5) conduct research to advance approaches to habitat assessment and fisheries management; 6) present assessment results and scientific advice to Regional Offices, FMC's, and others; 7) participate in FMP development; 8) defend habitat assessments in a court of law; 9) produce and peer-review scientific manuscripts for publication; 10) undertake training or train others on new methodologies; 11) participate in national and international conferences; and 12) undertake administrative duties depending on supervisory level. With limited exceptions, there is insufficient opportunity for individual scientists to focus on just one or a few of these activities due to an overall shortage of habitat scientists.

The HAIP Team surveyed NMFS habitat and ecosystem scientists, population/stock assessment scientists, and resource managers on the actual and optimal allocations of their time associated with various components of habitat assessments. Stock assessment scientists were asked to participate in the survey because many conduct habitat-related research and because of the HAIP's emphasis on habitat and ecological considerations in fisheries stock assessments. Scientists and managers were asked to estimate the percentage of their time, averaged over the previous two years, spent in each of ten activities: 1) the mechanics of habitat assessments; 2) modeling research to improve assessment methodology; 3) other research to improve habitat assess-

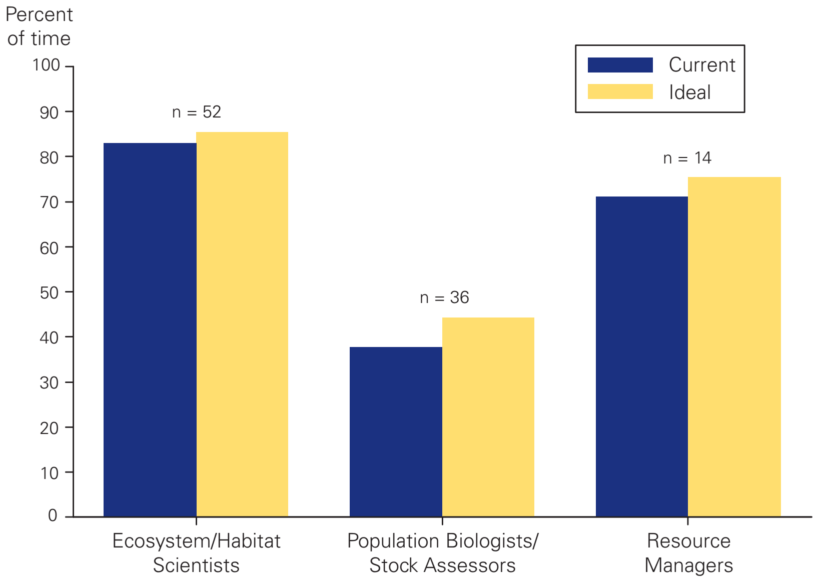


Figure 17
Percent of time (averaged from all respondents in each discipline) currently and ideally spent on all habitat-related activities by NMFS staff in three disciplines.

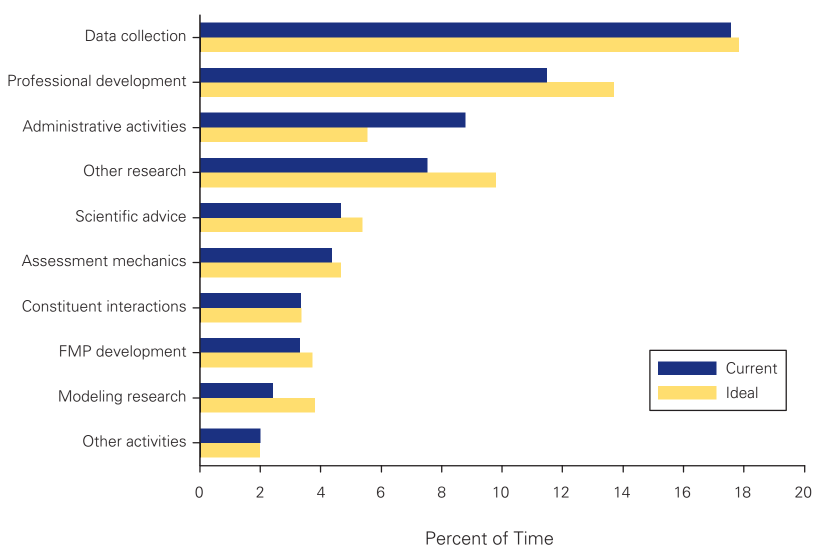


Figure 18
Percent of time (averaged from respondents across all regions) currently and ideally spent on specific habitat-related tasks for all regions combined.

ment methods and tools; 4) participation in collection, analyses, and management of data; 5) provision of scientific advice to FMC's; 6) participation in FMP development, evaluation of alternative management strategies, and other FMC-related activities; 7) other interactions with constituents; 8) professional development including producing manuscripts, reading journals, attending conferences, and training; 9) administrative duties; and 10) other. Respondents were also asked to estimate the ideal percentage of time that should be allocated to these activities.

Overall, habitat and ecosystem scientists spend about 83% of their time on habitat-related activities. Population/stock assessment scientists and resource managers spend about 38% and 71% of their time, respectively, on habitat-related activities. All three groups agree that ideally they could spend 3-7% more time on these activities (Figure 17).

All respondents (averaged across disciplines) similarly spend the most time on tasks such as data collection, professional development, administrative duties, and other habitat-related research (Figure 18). Differences did exist, however, among regions on the amount of time available to spend specifically on habitat-related tasks. For example, habitat and ecosystem scientists from the Southwest and Northeast Science Centers spend 100% of their time on habitat-related tasks, while researchers at the other Science Centers allocated 50-94% of their time to those duties. This emphasizes that some Science Centers have teams dedicated to ecosystem and habitat research, while teams at other Science Centers comprise a mix of staff that perform functions other than those related to habitat assessment. Resource managers spend the majority of their time on other activities, such as EFH consultations, habitat restoration and protection, nonfishing-related effects on habitat, and strategic planning. They also spend a fair amount of time on FMP development and data collection. All three groups agree that they require more time to accomplish most habitat-related tasks and spend too much of their available time performing administrative duties.

There were no substantial differences between the current allocation of time and the surmised ideal situation. This is an indication that the time of NMFS staff, regardless of discipline, is fully committed. NMFS staff have little occasion to shift duties or responsibilities, and they have limited time for habitat assessments and much less time to improve them. The conclusion of the HAIP Team is that additional staff will be necessary to achieve improvements to habitat assessments.

Section 5: Resource Requirements

At a Glance

- Major obstacles to producing and using credible habitat assessments include: lack of habitat-specific abundances and biological parameters; insufficient staff to collect, process, analyze, and model habitat data; and insufficient research on environmental and multispecies effects.
- Three Tiers of Excellence for Habitat Assessments include the essential elements of a comprehensive habitat assessment and monitoring program: habitat-specific biological information, geospatial information on habitat characteristics, and development and application of indices to monitor habitat condition related to fish production.
- About 5% of total NMFS staff are currently working on habitat-related activities at the Science Centers, and an alarming average of 33% of those staff working on habitat are contractors and students supported with transient, non NMFS funds.
- Full implementation of the HAIP will require a 250% increase in staff and a substantial increase in funds for program operations, tools, technology, and infrastructure.

Programmatic Needs

The HAIP team asked NMFS habitat and ecosystem scientists, population/stock assessment scientists, and resource managers to identify the most important factors hampering their ability to provide accurate, precise, valid, and defensible habitat assessments (including data collection, analyses, and reporting) that would assist in improving accuracy and precision of stock assessments and EFH/HAPC designations. From their average responses, habitat-specific abundance, the quantity of staff to collect necessary habitat-related data, and research on multispecies interactions were ranked as major obstacles to producing and using credible assessments, and were relatively high priorities for improvement of assessments (Figure 19). Taken as a whole (i.e. responses across all disciplines), research on environmental effects and habitat-specific biological parameters, and the quantity of staff to develop better habitat assessment models and to produce habitat analyses also ranked as major impediments to producing and using quality assessments. These seven categories also were consistently scored among the six Science Centers as being the greatest impediments to producing and using credible assessments and the highest priorities for improvement. On average, the population/stock assessment scientists identified fewer obstacles to quality habitat assessments than the other two groups, and the resource managers scored more topics as being major impediments to quality habitat assessments than the other two groups (Figure 19). Resource managers alone identified inadequate number of staff to communicate habitat-related results as one of the greatest obstacles to producing and using quality habitat assessments.

While not graphically depicted, some differences in average scores occurred among the Science Centers. For example, the Southeast Fisheries Science Center (SEFSC) considered more topics to be major obstacles to quality assessments, while the Alaska Fisheries Science Center (AFSC) and NWFSC scored fewer topics as high priorities. In addition, collection of habitat-specific commercial catch and effort data was considered a relatively high priority by researchers at the Pacific Islands Fisheries Science Center (PIFSC) and SEFSC, but not as much by the other four Centers. Across all the Centers, and regardless of discipline, the current quantity of scientists to communicate habitat-related results to NMFS constituents generally was thought to be adequate and a low priority for improvement.

Considering fishery-independent data needs, there were some differences in the average scores between respondents who work

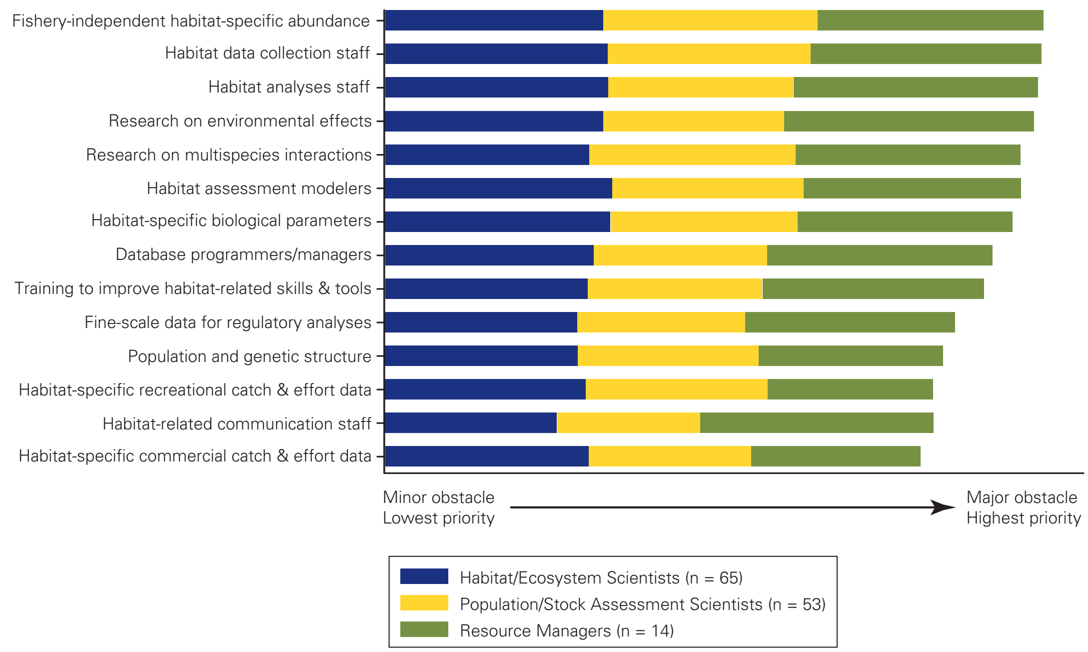


Figure 19

Obstacles to producing and/or using quality habitat assessments, averaged over responses from NMFS staff of three disciplines (habitat/ecosystem science; population/stock assessment science; and resource management).

on pelagic stocks and those who focus on demersal stocks (Figure 20). Respondents working on demersal species scored direct observation survey methods as a relatively high priority (especially as related to survey design, fish-habitat associations, and habitat-specific abundance or biomass from quantitative transects), while those respondents working on pelagic species did not need improved data from this type of survey. Respondents who work on either pelagic or demersal species did not need improved data from trawl surveys, and neither group thought that additional training courses on species identification for underwater surveys or for operation of multibeam acoustic equipment were needed.

While not graphically depicted, respondents from all six Science Centers identified increased sampling frequency (including habitat-specific, seasonal, and spawning surveys) as the highest priority fishery-independent data needed in order to enhance their ability to produce accurate, precise, and timely habitat assessments. More habitat-specific recruitment surveys and tagging studies (particularly archival and sonic tags) also were scored as top fishery-independent data needs by the Science Centers in general. Additionally, increased numbers of data managers, sample processors, and statistical staff were important to a majority of responders from all Science Centers.

The HAIP Team also asked managers of habitat and population assessment programs at the six Science Centers to identify the resources (e.g. data collection programs, assessment scientists, survey personnel, technicians, database managers, and computer programmers) needed to improve NMFS' habitat assessments. Their responses (one from each Center) reinforced those of their staff scientists; across all Science Centers, program managers ranked habitat data processing, habitat-specific biological parameters, and habitat-specific fishery independent indices of abundance as the three types of data or activity most needed to improve NMFS' habitat assessments (Figure 21). Increasing the number of scientists to develop improved habitat-related assessment models and habitat-specific commercial catch and effort data also ranked high for most Science Centers.

Three Tiers of Assessment Excellence

The quality of habitat assessments is represented using a series of tiers in a manner similar to other NMFS assessment improvement plans (NMFS, 2001; Appendix 3). The three tiers of the HAIP include the essential elements of a comprehensive habitat assessment and monitoring program: habitat-specific biological information, geospatial information on habitat characteristics,

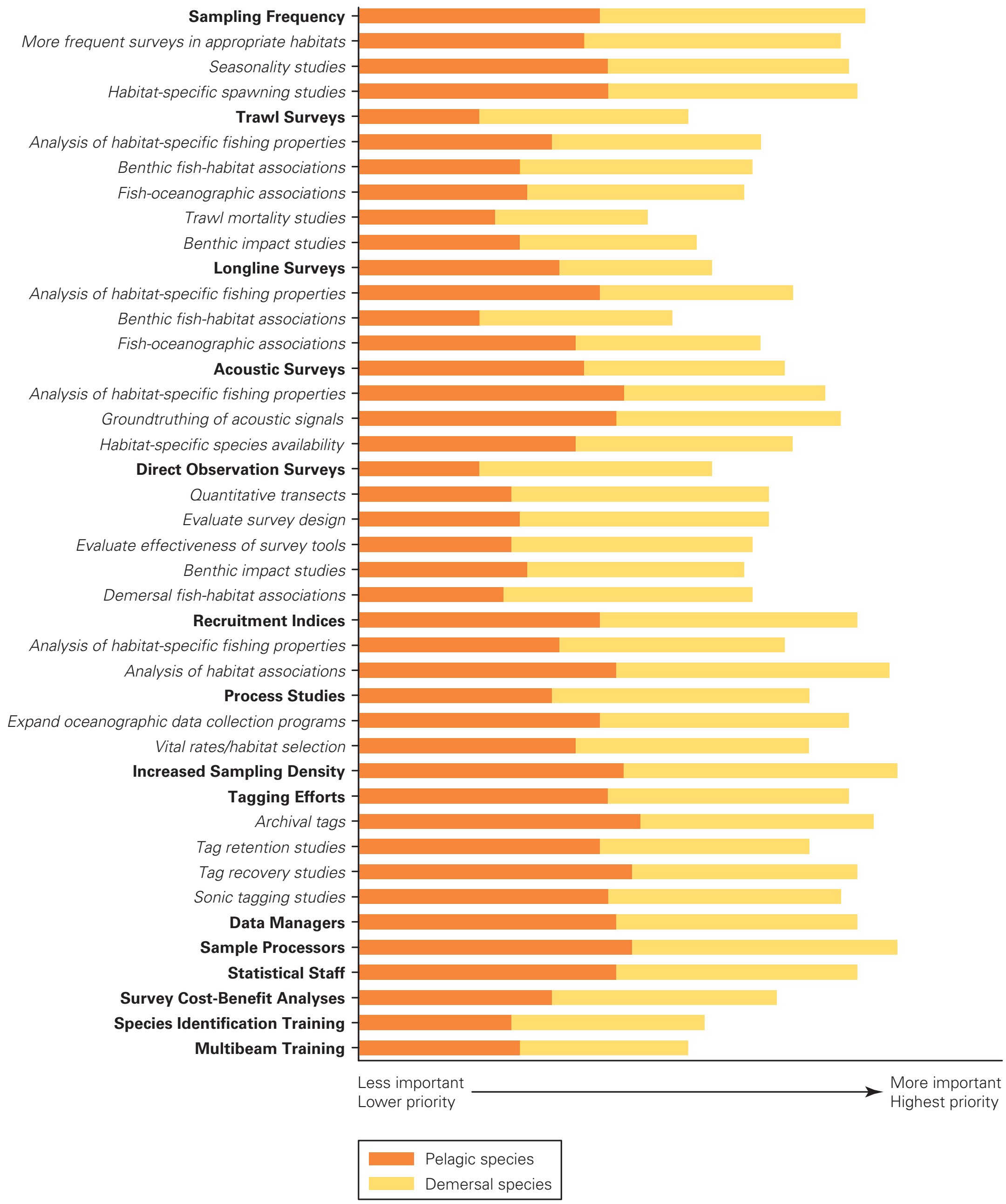


Figure 20
Fishery-independent data needs (grouped by bolded categories) as identified by 132 NMFS staff from six NMFS Fisheries Science Centers and three research disciplines (habitat/ecosystem scientists; population/stock assessment scientists; and resource managers), averaged by two fish stock life styles (pelagic and demersal).

and development and application of indices to monitor habitat condition related to fish production. The tiers indicate increasing levels of resolution in assessment data and an increased understanding of the functioning of fishery habitats.

Progress can be made, and already is being made in a limited manner, simultaneously on all three tiers of habitat assessment. The accomplishments in the lower tiers will enhance the success in the higher tiers, but this process does not preclude working on tasks identified in multiple tiers. Respondents to the HAIP Team's questionnaire indicated that research needs vary across Science Centers, and thus the order in which the three tiers are addressed and the rate of advancement through the tiers will be Center-specific and depend on the research emphasis, staff expertise, and available infrastructure at each Science Center. Fundamental to the three-tier assessment structure is a feedback loop that uses results from studies in the higher tiers to inform the prioritization process of the lower tiers (Figure 22).

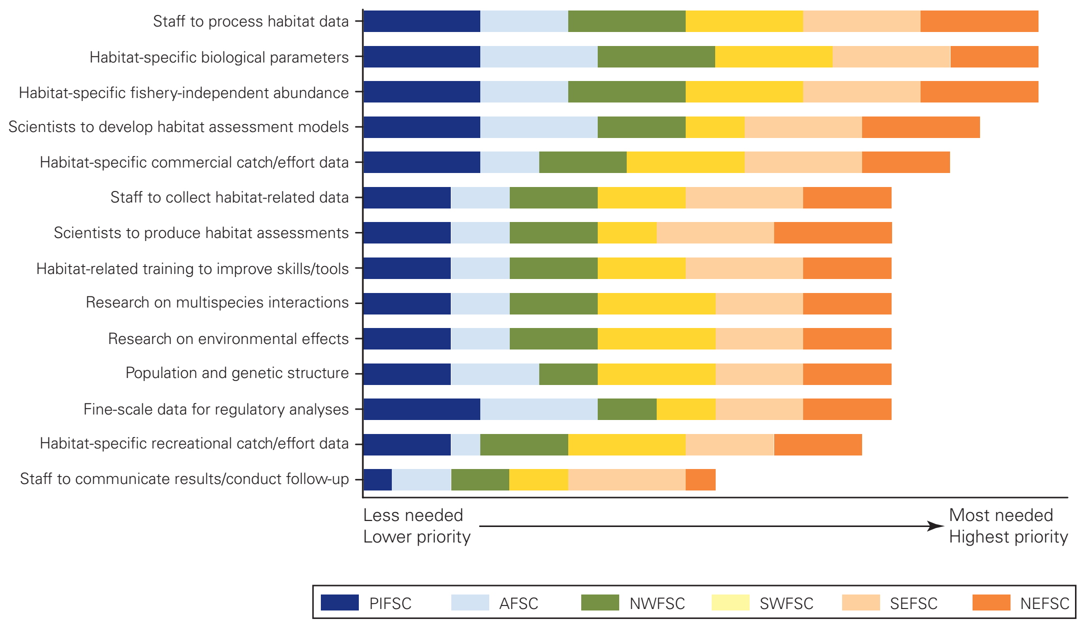


Figure 21

Resources most needed to produce and/or use quality habitat assessments, as identified by program managers at each of the six NMFS Fisheries Science Centers (one response per Center).

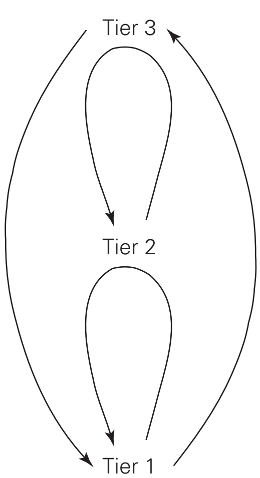


Figure 22

An illustration of the progress and feedback achieved among the three Tiers of Excellence for habitat assessments.

Tier 1 includes a comprehensive evaluation and synthesis of existing habitat information for FMP/FSSI stocks by life stage. Tier 1 habitat assessments can be developed at any level of specificity, depending on the available information. A minimum requirement is habitat-specific presence/absence species distribution, similar to EFH Level 1 data (Appendix 2). Tier 1 habitat assessments will result in limited improvements to EFH designations, associated risk assessments, and stock assessments (e.g. stock assessment analysts could have more information to identify, and perhaps adjust for, the effects of habitat on survey design and catch data). Completing Tier 1 habitat assessments will improve the knowledge base used to protect and conserve habitat, and will provide the much-needed basis for determining priorities for future research and development of assessment and monitoring capabilities. Tier 1 habitat assessments will be more thorough, timely, better quality-controlled, and better communicated than are the current assessments.

In Tier 2, new or expanded data collection and research initiatives will be required to achieve a higher level of habitat assessments. The minimum biological data requirement is habitat-specific densities of species and life stages, similar to EFH Level 2 data (Appendix 2). Habitat maps for each region will provide relevant detail for all life stages of all species. These maps and spatially explicit fish densities will be used to determine habitat-specific abundance or biomass. Habitat theory and proxies will be developed and applied to data-poor stocks. Habitat-specific coefficients of catchability will be developed for some species.

The surveys and monitoring required for Tier 2 habitat assessments should be conducted at appropriate temporal resolutions (i.e. monthly, seasonally, annually, or longer), depending on the vulnerability of specific habitat types to natural and anthropogenic impacts. Developing indices of habitat condition and evaluating impacts of habitat change on the abundance of stocks by life stage will be part of Tier 2 assessments, and sources of uncertainty will be identified for future research. Tier 2 products will be used in EFH amendments, improved fishery-independent surveys, stock assessments, and analyses related to habitat protection and conservation.

Tier 3 is the most challenging level of the HAIP, and will require substantial new or expanded data collection and research initiatives and the interdisciplinary cooperation among stock assessment scientists and habitat biologists and ecologists. Tier 3 habitat assessments will incorporate habitat-specific vital rates (e.g. growth, reproduction, survival, and production) of FMP/FSSI stocks by life stage, which is equivalent to EFH Levels 3 and 4 data (Appendix 2). Quantitative maps of habitat distribution and condition, which reflect appropriate temporal resolution, also will be required. Priorities identified in Tier 1 and Tier 2 will guide new studies of vital parameters and community interactions linked to habitat types or condition. To fully achieve Tier 3, these inputs of geospatial biological and physical habitat data will need to be obtained through regular monitoring, such that the dynamics of the stocks, habitats, and ecosystems can be tracked through space and time. Both Tier 2 and Tier 3 will require new ways to combine geospatial data, and advances in data analyses, display, and modeling that can incorporate diverse data into assessments.

Tier 3 habitat assessments will provide quantitative estimates of fish productivity by habitat and ecosystem considerations (such as multispecies interactions, environmental effects, and spatial and seasonal analyses) for incorporation into stock assessments, thereby helping to meet the SAIP Tier 3 goals (NMFS, 2001; Appendix 3). Tier 3 habitat assessments and the SAIP Tier 3 stock assessments they support will promote the development of meaningful IEA's. Understanding the relative importance and the functional mechanisms of the major factors that affect productivity of stocks is fundamental to the goals and indicators, ecosystem models, and monitoring programs that comprise the IEA process. Findings from Tier 3 habitat assessments will contribute to a body of habitat theory that is integral to the formulation and implementation of EBFM.

Timeframes and Relationships Among Tiers

Habitat assessments will vary by FMP stock, geographic scope, and application. It is likely that effort spent on a habitat assessment for one taxon may be relevant to taxa with similar habitat and life history traits. Even with this type of leveraging, Tier 2 and Tier 3 assessments will require a significant increase in staff and infrastructure for data collection and analyses.

The purpose of the HAIP tier system is to ensure that monetary investments and research efforts result in the necessary information to improve NMFS' habitat assessments. While there is some habitat data currently available in all three tiers, most are classified as being in Tier 1 at best. Progress ideally should be made simultaneously in all three tiers. Implementing the HAIP over time, Tier 1 assessments for prioritized stocks will be completed in an estimated 3-5 years. Tier 2 assessments could be achieved within a 10-year timeframe, contingent on timely increases in necessary infrastructure and number of staff. Achieving Tier 3 assessments for prioritized stocks could be at least 10 years from full implementation of the HAIP and will be subject to revised projections based on Tier 2 findings. Feedback from research results at the higher tiers to the prioritization process at the lower tiers will be necessary on a regular basis to realize an adaptive tiered framework.

National Staffing Requirements to Meet Tier Goals

The number of full-time staff currently assigned to habitat-related research activities and the number of additional staff required to achieve the objectives of each of the three Tiers of Excellence for habitat assessments have been summarized by type of habitat-related activity for each Science Center (Figure 23) and for all six Science Centers combined (Table 4); see Appendix 7 for region-by-region descriptions of habitat programs and staffing requirements at the six Science Centers. Program managers estimate that the equivalent of 221 full-time staff are currently working on habitat-related activities throughout NMFS; this amounts to about 5% of total NMFS staff (estimated at 4,090). An alarming average of 33% of the 221 staff are contractors and students supported with transient, non NMFS funds. The pursuit of marine fisheries habitat research in all the Science Centers has been possible due to the many successful partnerships with our academic colleagues and opportunistic funding from other NOAA offices, other Federal agencies, state agencies, and private foundations (Appendix 6). A comprehensive NMFS research program that is directly focused on the ecological value of marine habitats to fishery stocks and on IEA's will require significant additional funding from NMFS.

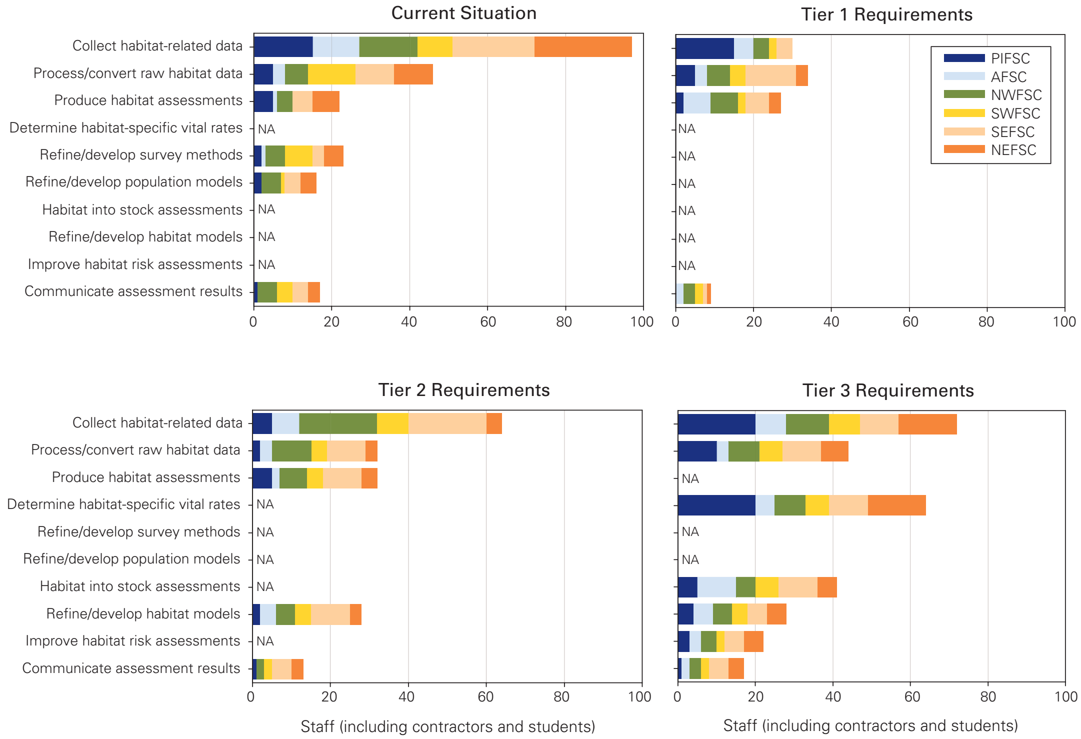


Figure 23

Current number of full-time staff, and the additional number of staff required to meet the criteria of the three Tiers of Excellence, for ten habitat-related activities at each NMFS Fisheries Science Center. Number of staff was estimated by program managers from each Center and includes permanent employees, as well as contractors and students that have only temporary funding. "NA" indicates that a habitat activity did not apply to a particular tier, according to the questionnaire.

NMFS program managers have estimated that 557 additional staff devoted to habitat research and assessments will be required to fully implement and support the HAIP; this is about a 250% increase over current staffing levels. Additional staff for collecting, processing, and communicating habitat-related data and for producing habitat assessments is needed in each of the three Tiers of Excellence. Implementation of Tier 1 (i.e. improvements to habitat assessments using existing data) will require modest increases in staffing levels (100 new positions nationwide), particularly for database managers, statisticians, GIS specialists, and other analytical staff. The additional demands associated with Tier 2 (i.e. estimating habitat-specific densities of species and life stages; assessing spatial extent of habitats) call for another 169 staff over current levels throughout NMFS. To achieve

Table 4

Number of additional full-time staff required to meet the three Tiers of Excellence by type of activity for all NMFS Fisheries Science Centers combined. Number of staff in each category does not necessarily reflect the absolute number of individuals involved in these activities, because some individuals may divide their time between several activities. Estimated numbers of staff include permanent employees, as well as contractors and students that have only temporary funding. Grey cells indicate that an activity did not apply in a particular tier, according to the questionnaire. See Appendix 7 for staffing requirements at each of the six Science Centers.

Activity	Current	Tier 1	Tier 2	Tiers 1+2	Tier 3	All Tiers
Collect habitat-related data	97	30	64	**94**	72	166
Process and convert raw habitat data into usable products	46	34	32	**66**	44	110
Produce habitat-specific assessments	22	27	32	**59**		59
Determine habitat-specific vital rates over time					64	64
Refine existing habitat-related survey methods/tools and develop new ones	23					
Refine existing population models and develop new habitat-related ones	16					
Incorporate habitat and ecosystem information into stock assessments at SAIP Tier 3					41	41
Refine existing habitat and ecosystem models and develop new ones			28	**28**	28	56
Develop improved habitat risk assessments					22	22
Communicate improved assessment results and conduct other follow-up work	17	9	13	**22**	17	39
Total	**221**	**100**	**169**	**269**	**288**	**557**

Tier 1 and Tier 2 habitat assessments, 269 new staff will be needed. For Tier 3 assessments, another 288 staff will be required to determine habitat-specific vital rates and incorporate habitat and ecosystem information into stock assessments. As part of these staffing needs, the HAIP Team recommends the establishment of a Habitat Assessment fellowship program, similar to the Stock Assessment and Economics fellowship programs, which would provide funding for graduate students and post-doctoral associates of specific disciplines to advance habitat modeling, evaluation, and assessment efforts.

The NEFSC currently has the largest habitat program (54 staff), followed by the SEFSC (47 staff), the NWFSC (40), the Southwest Fisheries Science Center (SWFSC) (33), the PIFSC (30), and the AFSC (17; Table 5). Considering the sum of Tier 1 and Tier 2 staffing requirements, the NEFSC requires an additional 44% staff above the current situation; the SEFSC (168%); the NWFSC (160%); the SWFSC (97%); the PIFSC (123%); and the AFSC (194%). In addition to new staff, improvements to data management and communication systems, program support (e.g. vessel contracts; advanced technology survey and experimental tools and equipment), and infrastructure will be necessary to meet the requirements of the three tiers. These additional operational costs are roughly estimated to be equal to the expected increases in staffing funds that will be required to advance the quality of habitat assessments to the highest tier.

The estimated number of additional staff reflects the ever-increasing demands being placed on NMFS to effectively conserve, protect, and manage fishery species and other LMR's within the U.S. EEZ; to consult on Federal actions that may impact marine habitats; to respond to threats to habitats, restore damaged habitats, and mitigate habitat loss; to understand the role of habitat in trophic and community interactions and other critical ecosystem processes; to provide increasingly fine-scale spatially explicit habitat data for improved stock assessment modeling; and to predict the effects of climate change on marine habitats and associated fishery species. Additionally, the HAIP staff requirements will complement other NMFS plans, in particular the SAIP (NMFS, 2001; Appendix 3), which addresses the resources needed to improve NMFS fishery stock assessments to an adequate or better level. The SAIP identifies the need to include habitat and ecosystem information in stock assessments to advance to the "Next Generation" of assessment science, but makes few provisions for the resources necessary to accomplish this significant task. These and related plans, initiatives, and activities (such as those related to protected resources and other non FSSI stocks) should be integrated as one comprehensive approach to fisheries stock assessments and EBFM.

Program Operation Needs: Tools, Technology, and Infrastructure

In addition to increased support for staffing, the habitat science program presented in the HAIP can only be realized with concomitant funds for needed program operations, including the necessary tools, technology, and infrastructure. NMFS' current level of available infrastructure and advanced technologies are inadequate to meet the needs for improved habitat assessments. Time on chartered vessels as well as on NOAA ships and advanced technology survey tools likely will be the most costly items needed to achieve improved assessments. Characterizing and delineating the area and boundaries of habitats for some stocks (e.g. west coast groundfish species in deep water or highly migratory tunas) will be an extensive undertaking that requires improved technologies and additional time at sea. Both remote and direct-observation technologies are needed to efficiently and

Center	Current	Tier 1	Tier 2	Tiers 1+2	Tier 3	All Tiers
PIFSC	30	22	15	37	63	100
AFSC	17	17	16	33	36	69
NWFSC	40	20	44	64	44	108
SWFSC	33	10	22	32	34	66
SEFSC	47	24	55	79	55	134
NEFSC	54	7	17	24	56	80
Summed Staff	221	100	169	269	288	557

Table 5
Number of additional full-time staff required to meet the three Tiers of Excellence for improved habitat assessments at each Science Center and for all Centers combined. Estimated number of staff includes permanent employees, as well as contractors and students that have only temporary funding.

accurately survey more area more frequently, and to accurately monitor important habitat attributes. Many of these technologies currently are being developed (for example, see Appendix 6), with emphasis on improving optical and acoustic sensors. Improved technology will integrate these sensors with more effective sampling platforms, such as increasing swath of area being surveyed by ships and aircraft in order to improve data collection efficiencies and increase resolution of the observations to improve accuracy of the data. Optical and acoustic sensors also are being integrated into submersibles, ROV's, and AUV's to increase sampling capability and versatility. A significant challenge in adopting enhanced sampling capabilities will be the management of the increased volume of data. Improved hardware and software will be necessary to efficiently process the data and to ensure data availability.

It will be important to assess the adequacy of current technologies and infrastructure that is available both nationally and regionally to support the goals established in the HAIP. By way of example, a careful inventory was conducted by the NEFSC to assess its current and future technology and infrastructure needs (Hare et al., 2007). They identified platforms and sampling devices that are appropriate to collect habitat data for various trophic levels of organisms. The HAIP Team recommends that similar assessments be conducted, perhaps through a series of regional and national workshops, in order to better estimate the level of operational (nonstaffing) support required to collect and analyze the habitat data identified in the HAIP.

The HAIP Team also recommends that a National Habitat Assessment Workshop (NHAW) be convened in the near future to begin implementation of the HAIP and to develop a prioritized agenda of current habitat topics to be addressed at small, focused workshops. Currently, NMFS supports biennial National Stock Assessment Workshops (NSAW) and National Economics and Social Science Workshops, which provide opportunities to build coordinated programs, address issues of national concern, and promote interdisciplinary research. The establishment of a comparable biennial national forum for habitat science would advance the implementation of the HAIP recommendations to develop a national habitat science program. Given that one of the major objectives of the HAIP is to integrate aspects of habitat into stock assessments, the HAIP Team recommends that the first NHAW be held in conjunction with the NSAW.

In addition to a biennial NHAW, the HAIP Team recommends that focused workshops be convened periodically (perhaps in conjunction with NHAW or other annual national meetings such as that of the American Fisheries Society) to address specific research topics (e.g. incorporation of habitat variables into a specific stock assessment). These workshops would provide a directed level of scientific discourse that could lead to the peer-reviewed publication of specific habitat assessments or to the development of budget initiatives.

Section 6: Measuring Performance

At a Glance

- Performance measures will help NMFS monitor HAIP accomplishments and demonstrate effectiveness of the HAIP investments.
- Output-oriented performance measures for the HAIP should track the quantity and quality of biological and geospatial information and habitat condition indices that contribute to habitat assessments of FSSI stocks.
- Outcome-oriented performance measures for the HAIP should track the number (or percentage) of FSSI stocks for which the role of habitat in stock dynamics has been assessed at increasing levels of understanding.

Performance measures are necessary for effective management of LMR's as well as the habitat assessment program, and are a requirement of the NOAA budget process. The formal adoption of performance measures is a function of the planning and budget process,[10] but should be guided by the HAIP. The HAIP, therefore, will provide context for and describe characteristics of performance measures so that the effectiveness of the investments made to improve habitat assessments can be tracked.

Development of performance measures begins with identification of a strategic goal or ultimate purpose of a plan (Espinosa, 2007). The strategic goal of the HAIP is to determine the function of habitats in the production of FSSI and other FMP stocks and related ecosystem processes in support of management decisions that are the mandated responsibility of NMFS. This information is interpreted through habitat assessment, defined as both a process and the products associated with obtaining, consolidating, analyzing, and reporting the best available information on habitat characteristics relative to the population dynamics of fishery species.

Performance is measured by tracking progress made from the starting condition (baseline) toward a target over a defined time period. A useful performance measure contains an indicator to be measured, a unit of measure for quantifying the indicator, a baseline that establishes the initial condition, and a target for the desired level of performance (Cohen and Bortniak, 2009). There is a hierarchy of performance measures, with numerous outputs (i.e. things that a program does, such as making observations) leading to a smaller number of outcomes (i.e. desired effects of the program).

Outcome performance measures relate to a program's mission and mandates and to the societal benefits they support, but these outcomes may be affected by many factors that are external to the program. Achieving and maintaining healthy and sustainable fisheries is an example of an outcome that addresses the mandates of the MSRA. A successful marine fisheries habitat science program will contribute to achieving this outcome, but other factors external to the program also play significant roles. Output performance measures, by contrast, are focused internally on the program, and address the quantity, quality, and timeliness of a program's products and services. Output measures relate to the program's productivity and activities, and are primarily affected by factors closely controlled by the program.

A coordinated suite of outputs and outcomes is needed to evaluate program performance and to justify continued growth of the program. In addition, both outputs and outcomes can be hierarchical. As a successful program grows, the outputs increase in quantity and sophistication, progressively contributing to more comprehensive outcomes that support NMFS' mission and provide increased benefits to society.

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[10]NMFS' policy directive for developing and adopting performance measures can be found at https://reefshark.nmfs.noaa.gov/f/pds/publicsite/documents/policies/33-102.pdf.

Performance measures for the HAIP should tie habitat assessments to NMFS mandates. The indicators must be quantifiable, respond to available resources, and track criteria relevant to the essential elements of a habitat science program. If possible, performance measure targets should refer to criteria that already have been formally adopted through legislation or regulations (e.g. EFH regulations; see Appendix 2), rather than adopt new, and possibly ad hoc, criteria. The EFH final rule requires that EFH information be reviewed and updated at least every five years. To be consistent with this requirement, it is suggested that all data syntheses and assessments related to performance measures should be evaluated and updated, as necessary, at least every five years.

Output-oriented performance measures for the HAIP (Table 6) should relate to the three Tiers of Excellence of habitat assessments (see Section 5, p. 49). These three tiers, in turn, are related to EFH Levels 1-4 data, which reflect the level of detail and sophistication of the underlying scientific information. The indicators for the output performance measures should track the scientific activities (e.g. habitat-specific surveys of fish stocks) and products (e.g. GIS maps of habitats) that are needed to produce habitat assessments at each tier. Outputs for Tier 1 would be based on the comprehensive discovery and synthesis of currently existing biological and geospatial information. Outputs for Tier 2 would be based on the development of quantitative data of habitat-specific densities and habitat availability, which provide statistically reliable stock abundance by habitat type. Outputs for Tier 3 would be based on the development of quantitative data of habitat-specific vital rates and monitoring data on habitat status, which will support statistically reliable assessments of stock productivity by habitat type.

All three tiers of habitat assessments include the development and application of habitat condition indices. These indices are numerical indicators for tracking the status and trends of habitat for each of the life stages of FSSI and other FMP stocks. These indices will provide essential measures for assessing change in the amount and condition of habitat and the effects on the carrying capacity of the environment, productivity, and the level of sustainable fishing. Examples of habitat condition indices include the area of an essential habitat for a particular life-history stage of an FSSI stock, such as salt-marsh edge for juvenile shrimp, or a measure of environmental quality, such as the volume of water with sufficient dissolved oxygen for a species to maintain normal physiological functions. At the highest level, these indices will contribute to assessments of ecosystem sustainability. Determining baselines will require detailed analyses of the current scientific literature and datasets; progress toward targets will depend on the resources made available as the HAIP program develops.

Outcome performance measures appropriate for the HAIP (Table 6) should relate to the provision of information on the function of habitats in the production of FSSI and other FMP stocks and ecosystem processes in the form of habitat assessments that support the scientific and management decisions of NMFS. These measures should be based on the graduated scale inherent in the three Tiers of Excellence of habitat assessments. The indicator and unit of the outcome performance measures would be the number (or percentage) of FSSI stocks for which habitat assessments address the role of habitats in determining stock dynamics at a given Tier of Excellence. Reaching these outcomes for each tier would provide fisheries scientists, stock assessors, and fisheries and habitat managers with comprehensive summaries of information on the role of habitat in determining the dynamics of FSSI stocks at the level of detail specific to each habitat assessment tier. For Tier 1, an outcome performance measure would be the number of habitat assessments that summarize the currently existing information on the relationships between the life stages of FSSI stocks and their habitats. For Tier 2, the outcome performance measure would be the number of habitat assessments that contain quantitative information on density of the life stages of FSSI stocks by habitat type. Outcome for Tier 3 would be measured by the number of habitat assessments that are based on habitat-specific rates of growth, reproduction, survival, and, ultimately, production of FSSI stocks. At present, the baseline for Tier 3 habitat assessments is nearly zero (see Figure 15, p. 44), especially when all life stages are considered. The recommended target would be Tier 3 habitat assessments for all 230 of the FSSI stocks.

Table 6

Potential output-oriented and outcome-oriented performance measures of the Habitat Assessment Improvement Plan.

Tier 1: Comprehensive evaluation and synthesis of existing information on the habitat associations for all life stages of FSSI stocks	
<u>Outputs</u>	
Biological Information	Number of life stages of FSSI stocks[1] for which existing habitat information has been assembled and interpreted. The minimum level of detail is presence/absence data by habitat type (EFH Level 1 data), but all levels of detail are relevant.
Geospatial Habitat Information	Number of habitat types that have been identified and described in sufficient detail for interpreting and mapping existing biological information for every life stage of FSSI stocks. The minimum level of detail is qualitative text descriptions and the portrayal of habitat associations on generalized regional maps.
Habitat Condition Indices	Number of life stages of FSSI stocks for which numerical indicators of the status and trends of habitat have been developed and applied in habitat assessments.
<u>Outcome</u>	
Habitat Assessments	Number of summaries of existing information on the relationships between life stages of FSSI stocks and their habitats, including application of habitat indices. The minimum level of detail is text description and portrayal, on generalized regional maps, of the distribution of these life stages and the occurrence of habitat types, but all levels of detail are relevant.
Tier 2: Quantitative estimates of habitat use by FSSI stocks and life stages	
<u>Outputs</u>	
Biological Information	Number of life stages of FSSI stocks for which density data are available by habitat type (EFH Level 2 data).
Geospatial Habitat Information	Area[2] for which geospatial information is available on the distribution of important habitat characteristics of the life stages of FSSI stocks, to be used with density estimates as relevant to stock assessments and related areas of fisheries science (e.g. survey design, catchability coefficients, habitat characterization).
Habitat Condition Indices	Number of life stages of FSSI stocks for which habitat condition indices have been developed and applied at the level of density by habitat type.
<u>Outcome</u>	
Habitat Assessments	Number of comprehensive summaries based on Tier 2 quantitative information on habitat-specific densitites of FSSI stocks.
Tier 3: Quantitative estimates of fish productivity by habitat for FSSI stocks	
<u>Outputs</u>	
Biological Information	Number of life stages of FSSI stocks for which growth, reproduction, survival rates (EFH Level 3 data), or productivity (EFH Level 4 data) within habitats are available.
Geospatial Habitat Information	Area of habitat of the life stages of FSSI stocks for which condition is monitored at spatial and temporal resolutions sufficient to support status assessments based on habitat indices at the level of growth, reproduction, survival, or production by habitat type.
Habitat Condition Indices	Number of life stages of FSSI stocks for which habitat condition indices have been developed and applied at the level of growth, reproduction, survival, or production by habitat type, and which can contribute to the science underlying EBFM decisions.
<u>Outcome</u>	
Habitat Assessments	Number of comprehensive summaries of Tier 3 quantitative information on the growth, reproduction, survival, or production of FSSI stocks by habitat type.

[1]Five life stages are recognized for most (but not all) of the 230 FSSI stocks: egg, larva, juvenile, adult, and spawning. Thus, the baseline and target would be assessed against approximately 1,150 life stages.

[2]Scale (e.g. square nautical miles, square kilometers, hectares) depends on life history of species and stage, type of habitat, and the scientific question being addressed.

Section 7: Connecting HAIP to Other Habitat Science Programs

At a Glance

- It is essential that NMFS continue to foster partnerships with other groups, both within and outside of NOAA.
- All partners will benefit from, as well as contribute to, the success of the HAIP.
- NMFS should unite with other NOAA line offices to develop a NOAA-wide strategic plan for habitat science and assessments.

Habitat science is conducted for a variety of reasons and with disparate objectives throughout NOAA, other Federal and state resource agencies, universities, and private institutions. The breadth of multidisciplinary expertise and the extent of physical resources necessary to conduct a coherent habitat science program have demanded that NMFS enter into partnerships not only with other NOAA offices but also with other governmental agencies (e.g. USGS, National Aeronautics and Space Administration) and nongovernmental entities (particularly academia). Most of these partnerships have been formed independently at each of the Science Centers on an ad hoc basis, drawing scientists together based on complementary research interests and needs. It is essential that NMFS continue to foster partnerships with other groups, both within and outside of NOAA.

To achieve its goals, the HAIP should especially complement, coordinate, and leverage the expertise found in existing NMFS programs. For example, NMFS' Advanced Sampling Technology Working Group (ASTWG) (Appendix 6) currently supports the development of sampling technology for stock assessments and the SAIP (Appendix 3) and could similarly assist in meeting the goals and objectives of the HAIP. ASTWG already has identified the characterization of benthic habitat as a key theme in its funding process, and has supported projects and workshops that contribute to improved habitat assessments (Somerton and Gledhill, 2005). HAIP also will coordinate with and enhance those programs focused on ecosystem synthesis, such as Fisheries and the Environment (FATE) (Appendix 6) and the Comparative Assessments of Marine Ecosystem Organization (CAMEO) (Appendix 6). The purpose of FATE is to encourage the inclusion of environmental data in the stock assessment process; this program potentially can play a significant role in developing approaches to include habitat-related parameters in stock assessments. CAMEO is an emerging effort between NMFS and the National Science Foundation that supports research on the complex dynamics controlling productivity, behavior, population connectivity, climate variability, and anthropogenic pressures associated with living marine resources and critical habitats.

Many potential non NMFS partners within NOAA have habitat-related interests and capabilities (see Appendix 6 for a more comprehensive synopsis). Within OAR, Sea Grant comprises 32 university-based programs, many of which conduct habitat research. Ocean Exploration and Research supports missions to explore unknown areas of the oceans aboard the dedicated vessel, *Okeanos Explorer*. Within the National Ocean Service (NOS), the National Centers for Coastal and Oceanic Science conduct and support research, monitoring, and assessments, focusing on estuaries, coral reefs, and National Marine Sanctuaries. NOS also manages programs that are integrated across line offices and can be important partners in HAIP-related activities. Habitat studies outlined in the HAIP will use and provide data in coordination with IOCM, as well the Integrated Ocean Observing System (IOOS) and regional subsystems. The integration and delivery of habitat data will adhere to IOOS standards for data-set descriptions (metadata), discovery, accessibility, and security.

The diverse data necessary for habitat delineation and assessment could be the first test of the use of the enterprise data systems being proposed for NMFS. Habitat activities outlined in the HAIP would add value to, as well as benefit from, ongoing NOAA matrix programs such as the Coral Reef Conservation Program (Appendix 6). Full implementation of the HAIP will contribute to both national and regional programs such as the National Status and Trends Program, the National Estuarine Eutrophication Assessment Program, the Monitoring and Event Response for Harmful Algal Blooms Research Program, the National Marine Sanctuaries habitat monitoring programs, and invasive species monitoring programs.

One partnership to which HAIP-directed research would be especially relevant is the National Fish Habitat Action Plan (NFHAP: http://fishhabitat.org/), which is assessing the causes of declines in fish habitat with an emphasis on inland, freshwater systems. Led by the U.S. Fish and Wildlife Service, partners include the USGS, the National Fish and Wildlife Foundation, fishing and conservation organizations and industry, and, more recently, NMFS. The NFHAP program has taken shape over the last several years, marked by the publication of the "Action Plan" in 2006 (Association of Fish and Wildlife Agencies, 2006) and the recent release of a draft report, "A Framework for Assessing the Nation's Fish Habitat" (National Fish Habitat Science and Data Committee, 2008). The first NFHAP national assessment will be completed in 2010, with updates planned at 5-year intervals. NMFS' participation in future assessments could provide vital coastal and marine components, given sufficient resources, requisite data, and improved assessments generated by the HAIP.

Despite the diversity of other habitat-related efforts both within and outside of NOAA, the research proposed in the HAIP is unique in its focus on habitat functions in relation to fishery productivity and in linking habitats with FSSI and other FMP stocks. This habitat science has been recognized as a need within NMFS for some time, and implementation of the HAIP will address gaps in the stock assessment process as well as provide a way forward for NOAA to develop EBFM. NMFS should unite with other NOAA line offices to develop a NOAA-wide strategic plan for habitat science and assessments.

Section 8: The Benefits of Implementing the HAIP

The Marine Fisheries Habitat Assessment Improvement Plan (HAIP) defines NMFS' unique role in conducting habitat science and in developing habitat assessments to meet its mandated responsibilities to sustain marine fisheries and associated habitats. A coordinated national program envisioned through the HAIP will result in improved science addressing the relationships between fishery species and their habitats, which is fundamental to meeting the agency's mandates and is a major goal of many NMFS strategic planning documents. Moreover, the habitat needs identified in the HAIP concur with the priorities for habitat research that have been identified by each Science Center in NMFS' Our Living Oceans habitat report (NMFS, In press) and in the strategic plan for NOAA's Habitat Program (NMFS, 2009c; Appendix 8).

Through the HAIP, NMFS offers a guide to conduct its diverse habitat research, monitoring, and assessments and to develop budget alternatives and increased support for habitat science. A comprehensive NMFS research program that is directly focused on the ecological value of marine habitats to fishery stocks and on integrated ecosystem assessments (IEA's) will require significant additional funding from NMFS.

Improved habitat science capabilities and products that result from a fully supported and implemented HAIP will meet the mandated needs of NMFS. Improved habitat data collection and analytical methods, and coordinated and comprehensive habitat inventories, assessments, and indicators are critical in understanding the role of habitat in fish and fishery production. Developing this information through the HAIP and effectively communicating it to managers, stakeholders, and the general public will provide important benefits to the nation.

With full support and implementation of the HAIP:

- NMFS will improve its capabilities to identify those habitats critical to the sustainability of our nation's fisheries, living marine resources, and ecosystems. This will lead to:
    - More rigorous, quantitative habitat assessments that enable NMFS to more efficiently and effectively identify and protect EFH and HAPC from fishing and other impacts;
    - Reduced risks to fish production, and many other ecosystem services, due to habitat degradation or loss; and
    - More effective habitat restoration projects that enhance fish production.

- Scientists will have habitat information at appropriate spatial and temporal scales to improve design and interpretation of stock surveys and to use in current stock assessment models and support model improvements. This will lead to:
    - Improved field surveys;
    - Improved stock assessments; and
    - Reduced need for high precautionary limits in fisheries management.

- NMFS will have the necessary information to deliver high-quality habitat science that can be readily applied by fishery managers. This will lead to:
    - A more comprehensive understanding of the role of habitat in trophic and community interactions and other critical ecosystem processes, resulting in successful ecosystem-based fishery management (EBFM); and
    - Fishery management decisions that have a greater positive impact on the long-term sustainability of habitats, fish production, and many other ecosystem services.

- NMFS will better understand, monitor, and predict the effects of climate change and other anthropogenic impacts on marine habitats and associated species distribution, reproduction, growth, and survival. This will lead to:
    - Significant advancements in the implementation of EBFM;

- Increased efficiency in conducting and applying marine habitat science; and
- Fishery management decisions that are robust to the effects of climate change and other anthropogenic impacts.

o The nation will be better able to address conflicting demands on limited marine resources through effective coastal and marine spatial planning and IEA's. This will lead to:
  - Reduced impacts to coastal and marine habitats and fish stocks;
  - Increased ecosystem health and sustainability; and
  - The preservation of critical ecosystem services that support the social and economic well-being of the nation.

o Controversy surrounding management decisions will be reduced, thereby allowing NOAA and NMFS to focus on the most pressing scientific and management issues and to reduce costs and delays associated with litigation.

o NMFS partnerships, both within and outside of NOAA, will benefit in their mutual pursuits of habitat delineation and assessment efforts.

Section 9: Recommendations

The HAIP is the first step in building a comprehensive, coordinated national science-based enterprise to effectively evaluate, monitor, and manage habitats for coastal and marine fishery species. To that end, the HAIP Team makes the following recommendations:

- NMFS and NOAA should develop new budget and staffing initiatives to fund habitat science that is directly linked to NMFS mandates.

- NMFS should develop criteria to prioritize stocks and geographic locations that would benefit from habitat assessments.

- NMFS' habitat and stock assessment scientists should work together to initiate demonstration projects that incorporate habitat data into stock assessment models, perhaps focusing on well-studied species.

- NMFS should identify and prioritize data inadequacies for stocks and their respective habitats, as relevant to information gaps identified in the HAIP.

- NMFS should increase collection of habitat data on fishery-independent surveys and develop a plan for better utilizing new technologies (e.g. multibeam sonars) aboard the expanding NOAA fleet of Fishery Survey Vessels (FSV's).

- NMFS habitat scientists should engage partners within and outside of NOAA to exchange information about programs and capabilities. Habitat data collection efforts and data management initiatives should be coordinated and data management systems and integration applications should be upgraded and expanded to improve data accessibility and syntheses.

- NMFS should convene regional and national workshops to develop strategies to integrate habitat science and assessments, stock assessments, and IEA's. Workshops will advance the implementation of the HAIP and foster communication among habitat/ecosystem researchers, stock assessment scientists, and resource managers.

- NMFS should establish a habitat assessment fellowship program and provide funds to graduate students and post-doctoral associates of specific subdisciplines that would advance habitat modeling, evaluation, and assessment efforts.

- NMFS should unite with other NOAA line offices to develop a NOAA-wide strategic plan for habitat science and assessments in support of the nation's ocean policy priorities for EBFM, CMSP, and the use of IEA's.

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List of Acronyms

ADAPT: adaptive framework-virtual population analysis stock assessment model
AFSC: NMFS Alaska Fisheries Science Center
AKRO: NMFS Alaska Regional Office
ASPIC: A Stock Production Model Incorporating Covariates
ASTWG: NMFS Advanced Sampling Technology Working Group
AUV: autonomous underwater vehicle
CAMEO: Comparative Assessments of Marine Ecosystem Organization
CFMC: Caribbean Fishery Management Council
COP: U.S. Commission on Ocean Policy
CMSP: coastal and marine spatial planning
CPUE: catch-per-unit-of-effort
DIDSON: dual-frequency identification sonar
DPSIR: driver-pressure-state-impact-response
EBFM: ecosystem-based fisheries management
EEZ: Exclusive Economic Zone
EFH: essential fish habitat
EIS: Environmental Impact Statement
ESA: Endangered Species Act
F/HC: NMFS Office of Habitat Conservation
F/ST: NMFS Office of Science and Technology
FATE: Fisheries and the Environment program
FMC: Fishery Management Council
FMP: Fishery Management Plan
FRAM: NWFSC Fishery Resource Analysis and Monitoring division
FSSI: NMFS Fish Stock Sustainability Index
FSV: Fishery Survey Vessel
GAM: generalized additive model
GMFMC: Gulf of Mexico Fishery Management Council
GIS: geographic information systems
GOMC: Gulf of Maine Council on the Marine Environment
HAIP: "Habitat Assessment Improvement Plan"
HAPC: habitat areas of particular concern
HMS: highly migratory species
IEA: integrated ecosystem assessment
IOCM: Integrated Ocean and Coastal Mapping
IOOS: U.S. Integrated Ocean Observing System
LIDAR: light detection and ranging
LME: large marine ecosystem
LMR: living marine resource
LNG: liquefied natural gas
M: natural mortality for a fish stock
MAFMC: Mid-Atlantic Fishery Management Council
MPA: marine protected area
MSRA: Magnuson-Stevens Conservation and Management Reauthorization Act of 2006

NCCOS: NOAA's National Centers for Coastal Ocean Science
NEFMC: New England Fishery Management Council
NEFSC: NMFS Northeast Fisheries Science Center
NFHAP: National Fish Habitat Action Plan
NHAW: National Habitat Assessment Workshop
NMFS: NOAA's National Marine Fisheries Service
NOAA: National Oceanic and Atmospheric Administration
NOS: NOAA's National Ocean Service
NPFMC: North Pacific Fishery Management Council
NRC: National Research Council
NSAW: National Stock Assessment Workshop
NURP: NOAA's National Undersea Research Program
NWFSC: NMFS Northwest Fisheries Science Center
OAR: NOAA's Office of Oceanic and Atmospheric Research
OE: Office of Ocean Exploration in OAR
PFMC: Pacific Fishery Management Council
PIFSC: NMFS Pacific Islands Fisheries Science Center
q: catchability coefficient
ROV: remotely operated vehicle
SAFMC: South Atlantic Fishery Management Council
SAIP: "Marine Fisheries Stock Assessment Improvement Plan"
SEAMAP: Southeast Area Monitoring and Assessment Program
SEFSC: NMFS Southeast Fisheries Science Center
SOOP: Ship-Of-Opportunity Program
SS: Stock Synthesis
SSH: sea surface height
SST: sea surface temperature
SWFSC: NMFS Southwest Fisheries Science Center
USGS: U.S. Geological Survey
WPFMC: Western Pacific Fishery Management Council

Appendix 1: Summary of Major U.S. Habitat Conservation Legislation

Note: There are many U.S. legislative mandates pertaining to habitat. This list includes the major mandates that apply to the National Marine Fisheries Service (NMFS); the summaries are of specific aspects that apply to habitat conservation, protection, and recovery.

Acts / Executive Orders	Summary	NOAA Lead	Date
Magnuson-Stevens Fishery Conservation and Management Act	• Established U.S. management authority over the U.S. Exclusive Economic Zone (generally 3-200 nautical miles from shore). Also established eight Regional Fishery Management Councils (FMC's) with responsibility for the preparation of fishery management plans (FMP's) to sustainably manage fishery stocks and their habitats within their regions. • States that any FMP may include management measures in the plan to conserve target and nontarget species and habitat, considering the variety of ecological factors affecting fishery populations. • Defines essential fish habitat (EFH) and includes provisions for conserving EFH through the following: 1) identify and describe EFH for managed species in FMP's; 2) minimize the adverse effects of fishing on EFH to the extent practicable; and 3) identify other actions to conserve and enhance EFH. The Act further requires that Federal agencies consult with NMFS on actions that may adversely affect EFH and that NMFS provide conservation recommendations to those agencies. • Directs Secretary of Commerce to establish a Deep-Sea Coral Research and Technology Program that will identify existing information; map locations of deep-sea coral habitats; monitor activities in these habitats; conduct research; develop technologies to reduce interactions between fishing gear and deep-sea corals; prioritize activities; and provide information to FMC's to aid in the conservation and management of these important habitats. The Act further authorizes FMC's to designate zones to protect deep-sea coral habitats from damage caused by fishing gear under FMP discretionary provisions.	NMFS	1976 (as amended by the Sustainable Fisheries Act in 1996 and the Magnuson-Stevens Reauthorization Act (MSRA) in 2006)
Endangered Species Act (ESA)	Provides for the protection and conservation of endangered and threatened species as well as the habitats and ecosystems upon which they depend. Requires the identification and protection of Critical Habitat (defined as habitat necessary for breeding, spawning, rearing, migrating, feeding, or sheltering) for every species listed under the ESA, and issuance of Biological Opinions for all Federal actions that may impact the critical habitat of any listed species.	NMFS	1973
Marine Mammal Protection Act	Provides for the protection of all species of marine mammals, regardless of their status under the ESA. Restricts any alterations to habitat that could adversely impact stocks of marine mammals through disruption of behavioral patterns that include, but are not limited to, migration, breathing, nursing, breeding, feeding, and sheltering.	NMFS	1972 (as amended)
Coral Reef Conservation Act	Provides NOAA with additional authority to undertake a number of activities (including mapping, monitoring, assessment, research, and restoration) to understand, manage and protect coral reef ecosystems. Authorizes the establishment of the Coral Reef Conservation Fund and provides matching grants for coral reef conservation projects.	NOAA	2000
Marine Protected Areas Executive Order 13158	Purposes are to: strengthen the management, protection, and conservation of existing marine protected areas (MPA's) and establish new or expanded MPA's; develop a scientifically based, comprehensive national system of MPA's representing diverse U.S. marine ecosystems, and the Nation's natural and cultural resources; and avoid causing harm to MPA's through Federally conducted, approved, or funded activities. Establishes a MPA Center tasked with the development of a framework for a national system of MPA's and providing the information, technologies, and strategies to support the system.	NOAA	2000
Clean Water Act (Federal Water Pollution Control Act)	Aims to prevent destruction of aquatic ecosystems, including wetlands, by authorizing water quality and pollution research and addressing a number of other water quality issues. Provides for Federal regulation of water quality through measures such as water quality standards, discharge limits, and permits, as well as permits to dredge and fill waters of the United States.	NMFS	1972
National Environmental Policy Act	Requires Federal agencies to analyze the potential effects of any proposed Federal action that would significantly affect historical, cultural, or natural aspects of the environment. The required analysis must include consideration of the environmental effects of a range of alternatives.	NOAA	1969

Acts/ Executive Orders	Summary	NOAA Lead	Date
Federal Power Act	Provides authority to issue mandatory fish passage prescriptions and recommend hydropower license conditions to protect, mitigate damages to, and enhance anadromous fish. Applies to licenses issued by the Federal Energy Regulatory Commission for non Federal hydropower projects.	NMFS	1920
Coastal Zone Management Act	Provides for the management of the nation's coastal resources, including the Great Lakes, and balances economic development with environmental conservation. Establishes the National Coastal Zone Management Program and the National Estuarine Research Reserve System. The Act also enables states to conserve habitat through the Federal permitting process.	NOS	1972 (as amended)
Comprehensive Environmental Response, Compensation, and Liability Act (Superfund Act)	Requires NOAA to seek damages from those who have released hazardous substances that have caused injury to natural resources (e.g. habitats). Accordingly, NOAA (NOS) determines injuries to natural resources and seeks recoveries from the potentially responsible parties to restore, replace, or acquire the equivalent of natural resources and to cover the costs of damage assessment. NMFS assists in developing and implementing restoration in certain cases; however, the assessment of injuries, development of the economic claim, development of the damage assessment, and restoration plan is a function of NOS. The Office of General Council for Natural Resources reviews all documents, advises, and negotiates the claim–hence this is a multiline office effort within NOAA.	NOS	1980
Estuary Restoration Act	Established the Estuary Habitat Restoration Council that includes NOAA, and authorizes funding for a comprehensive program to restore habitat in America's estuaries.	NOAA	2000
Fish & Wildlife Coordination Act	Requires Federal Agencies to consult with NMFS (also U.S. Fish and Wildlife Service and state resource agencies) concerning any project that may affect waters of the United States to ensure fish and wildlife resources are given equal consideration in water resource development.	NMFS	1958
Coastal Wetlands Planning, Protection, and Restoration Act	Established task force that includes NOAA (represented by NMFS) to develop a comprehensive approach to restoring and preventing loss of coastal wetlands in Louisiana.	NOAA	1990
Coral Reef Protection Executive Order 13089	Established the interagency U.S. Coral Reef Task Force, which is charged with developing and implementing a comprehensive program of research and mapping to inventory, monitor, and identify the major causes and consequences of degradations of coral reef ecosystems. The order also directs Federal agencies to do the following: 1) avoid harm to coral reef ecosystems through Federal actions; 2) expand their own research, preservation, and restoration efforts; 3) support international coral reef conservation efforts; and 4) address the U.S. role in international trade of coral reef species.	NMFS and NOS share lead	1998
National Marine Sanctuaries Act (Title III of the Marine Protection, Research, and Sanctuaries Act)	Provides for protection of areas designated as marine sanctuaries due to their special natural or cultural resource qualities by the following methods: 1) requiring NOAA to issue regulations and providing for civil penalties; 2) requiring NOAA to seek damages from those who have injured sanctuary resources (NOAA uses the money mainly to restore the injured resources); and 3) requiring other Federal agencies to consult with NOAA if they are proposing an action likely to injure sanctuary resources and, should they fail to follow NOAA's recommendations, to restore any injured sanctuary resources.	NOS	1972 (as amended)
Oil Pollution Act	Requires NOAA to seek damages from those who have released oil and caused injury to natural resources. Accordingly, NOAA (NOS) determines the injuries to natural resources and seeks recoveries from the potentially responsible parties to restore, replace, or acquire the equivalent of natural resources and to cover the costs of damage assessment.	NOS	1990
Atlantic Coastal Fisheries Cooperative Management Act (Atlantic Coastal Act)	Requires the development, implementation, and enforcement of coastal fishery management plans to promote interstate conservation and management of Atlantic coastal fishery resources. The Act provides a mechanism to ensure Atlantic coastal state compliance with mandated conservation measures in FMP's approved by the Atlantic States Marine Fisheries Commission.	NMFS	1993 (as amended)

Appendix 2: Summary of Essential Fish Habitat (EFH) Regulations and Programs

The Magnuson Fishery Conservation and Management Act was originally passed in 1976 and added amendments in 1986 that required FMC's to evaluate the effects of habitat loss or degradation on their fishery stocks and take actions to mitigate such damage. In 1996, this responsibility was expanded to ensure additional habitat protection with the addition of EFH provisions in the Sustainable Fisheries Act,[1] which, among other things, amended the habitat provisions of the Magnuson Act. The renamed Magnuson-Stevens Act called for direct action to stop or reverse the continued loss of fish habitats and mandated the identification of habitats essential to managed species and measures to conserve and enhance this habitat. The Act required cooperation among the NMFS, the FMC's, fishing participants, Federal and state agencies, and others in achieving the goals of habitat protection, conservation, and enhancement.

EFH is defined as "... those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity".[2] For the purposes of interpreting the definition of EFH, "waters" include aquatic areas and their associated physical, chemical, and biological properties that are used that are used by fish and may include aquatic areas historically used by fish where appropriate; "substrate" includes sediment, hard bottom, structures underlying the waters, and associated biological communities; "necessary" means the habitat required to support a sustainable fishery and the managed species' contribution to a healthy ecosystem; and "spawning, breeding, feeding, or growth to maturity" covers a species' full life cycle.[3]

FMC's must identify and describe in their Fishery Management Plans (FMP's) the habitats used by all life history stages of each managed species in their fishery management units. EFH that is judged to be particularly important to the long-term productivity of populations of one or more managed species, or to be particularly vulnerable to degradation, should be identified as "habitat areas of particular concern" (HAPC) to help provide additional focus for conservation efforts. After identifying and describing EFH, FMC's must assess the potential adverse effects of all fishing activities and gear types to EFH and must include management measures to minimize adverse effects, to the extent practicable, in FMP's. The FMC's are also directed to examine nonfishing sources of adverse impacts that may affect the quantity or quality of EFH and to consider actions to reduce or eliminate the effects. FMC's are further directed to identify proactive means to further the conservation and enhancement of EFH.

FMC's are required to obtain information to describe and identify EFH from the best available sources, including peer-reviewed literature, unpublished scientific reports, data files of government resource agencies, fisheries landing reports, and other sources. FMP's should identify gaps in habitat data and deficiencies in data quality (including considerations of scale and resolution; relevance; and potential biases in collection and interpretation) and must demonstrate that the best scientific information available was used in the identification and description of EFH, consistent with National Standard 2. The information necessary to identify and describe EFH is organized according to a series of data levels:

- *Level 1: Distribution data are available for some or all portions of the geographic range of the species.* At this level, only distribution data are available to describe the geographic range of a species (or life stage). Distribution data may be derived from systematic presence/absence sampling and/or may include information on species and life stages collected opportunistically. In the event that distribution data are available only for portions of the geographic area occupied by a particular life stage of a species, habitat use can be inferred on the basis of distributions among habitats where the species has been found and on information about its habitat requirements and behavior. Habitat use may also be inferred, if appropriate, based on information on a similar species or another life stage.
- *Level 2: Habitat-related densities of the species are available.* At this level, quantitative data (i.e. density or relative abundance) are available for the habitats occupied by a species or life stage. Because the efficiency of sampling methods is often affected by habitat characteristics, strict quality assurance criteria should be used to ensure that density estimates are comparable among methods and habitats. Density data should reflect habitat utilization, and the degree that a habitat is utilized is assumed to be indicative of habitat value. When assessing habitat value on the basis of fish densities in this manner, temporal changes in habitat availability and utilization should be considered.
- *Level 3: Growth, reproduction, or survival rates within habitats are available.* At this level, data are available on habitat-related growth, reproduction, and/or survival by life stage. The habitats contributing the most to productivity should be

[1]U.S. Public Law 104-297.
[2]16 U.S.C. 1802(10).
[3]EFH Final Rule, 67 FR 2375.

those that support the highest growth, reproduction, and survival of the species (or life stage).

- *Level 4: Production rates by habitat are available.* At this level, data are available that directly relate the production rates of a species or life stage to habitat type, quantity, quality, and location. Essential habitats are those necessary to maintain fish production consistent with a sustainable fishery and the managed species' contribution to a healthy ecosystem.

FMC's should strive to obtain data sufficient to describe habitat at the highest level of detail (i.e. Level 4).

The EFH components of FMP's should be reviewed periodically by the FMC's and NMFS to ensure that information is current and applicable. Each EFH FMP amendment is required to include a provision requiring review and update of EFH information and preparation of a revised FMP amendment if new information becomes available. The schedule for this review is based on an assessment of both the existing data and expectations of when new data will become available. This information is reviewed as part of the annual Stock Assessment and Fishery Evaluation Report preparation. A complete review of EFH information should be completed by the FMC's as recommended by the Secretary of Commerce, but at least once every five years.

The Magnuson-Stevens Act requires all Federal agencies to consult with NMFS on all actions, or proposed actions, authorized, or funded, or undertaken by the agency, that may adversely affect EFH. An EFH consultation consists of three steps:

1) The Federal action agency must submit a complete EFH Assessment to NMFS with information on the effects of the action on EFH. Such assessments must contain: a description of the proposed action; an analysis of the effects (including cumulative effects) of the proposed action on EFH, the managed species, and associated species; the agency's views regarding the effects of the actions on EFH; proposed mitigation, if applicable; and additional information such as the results of an on-site inspection to evaluate the habitat and site-specific effects of the project, the views of recognized experts on the habitat or species that may be affected, a review of pertinent literature and related information, an analysis of alternatives to the proposed action, and other relevant information.
2) NMFS responds to the Federal action agency with formal EFH conservation recommendations.
3) The action agency will then respond in writing to NMFS with a description of measures proposed by the agency for avoiding, mitigating, or offsetting the impact of the activity on EFH. In the case of a response that is inconsistent with NMFS conservation recommendations, the Federal agency must explain its reasons for not following the recommendations, including the scientific justification for any disagreements with NMFS over the anticipated effects of the proposed action and the conservation measures needed.

For additional information on the Essential Fish Habitat Program and Regional EFH contacts, please visit the EFH homepage at: http://www.nmfs.noaa.gov/habitat/habitatprotection/efh/index.htm.

Appendix 3: Executive Summary of the "Marine Fisheries Stock Assessment Improvement Plan" (NMFS, 2001)

- The Stock Assessment Improvement Plan is the report of the National Marine Fisheries Service (NMFS) National Task Force for Improving Fish Stock Assessments, and is a component of the Science Quality Assurance Program. The Task Force consisted of one representative from NMFS Headquarters and 1-2 representatives from each of the five NMFS Science Centers. The report also addresses recommendations made in the National Research Council study on Improving Fish Stock Assessments (NRC 1998a).

- Improvements in stock assessments area required for several reasons, including: that management entities are "managing at the edge" for many species, and therefore require the most accurate and precise stock assessments possible; it is no longer permissible to overfish; and there are currently increased demands for adopting a "precautionary approach" and incorporating "ecosystem considerations" into stock assessments and fisheries management. This report discusses these and other factors that define NMFS' stock assessment mandate.

- Although the NRC study on Improving Fish Stock Assessments (NRC 1998a) focused on improving assessment methodology, the Task Force agreed that the greatest impediment to producing accurate, precise, and credible stock assessments is the lack of adequate input data, in terms of the quantity, quality, and type of data available.

- For most stocks, there is at least basic information on landed catch and the size frequency of the catch. However, for more than 40% of the 904 stocks listed in the 1999 Report to Congress on the Status of Fisheries of the United States (NMFS 1999a), there is no fishery-independent or fishery-dependent index of abundance, which makes it extremely difficult to conduct a meaningful assessment. Other factors, such as the need to prioritize the stocks to be assessed, result in a total of about 60% of the stocks (545 stocks) lacking assessments sufficient to evaluate stock status relative to overfishing. On the other hand, although there are relatively few stocks with comprehensive input data, a total of 119 stocks are routinely assessed using state-of-the-art age or size structured models, some of which may also incorporate spatial and oceanographic effects. With a few exceptions, all of the high-valued, high-volume, or high-profile species are routinely assessed, while most of the unassessed species contribute little or nothing to total landings.

- Stock assessments conducted by NMFS are rarely, if ever, the product of a single individual, and peer review is an integral part of the process related to provision of scientific advice in support of fisheries management that are carried out by fisheries scientists from within and outside of NMFS. All five Science Centers have systems in place for peer review of stock assessments.

- The most important programmatic needs vary by region, and even by species groups within regions. Overall, the two most important needs are research vessel surveys designed to produce fishery-independent indices of abundance and to collect related information on spatial and temporal distributions, associated species, habitat, and oceanographic variables; and observer programs that provide information on species composition, amounts of each species kept and discarded, and fishing effort.

- Assessment scientists are faced with many demands. Within a given year, an individual assessment scientist may be expected to: (i) participate in fishery-independent surveys or other field work, (ii) provide input and advice on sampling designs for research surveys and other fishery-independent data collection activities, (iii) spend time on commercial or recreational fishing vessels, (iv) provide input and advice on the development of data collection objectives and protocols for observer programs and other fishery-dependent data collection activities, (v) conduct quality control or other preprocessing of data, (vi) conduct stock assessments, (vii) conduct research into stock assessment methods, (viii) present assessment results to peer review panels and constituent groups, (ix) participate on peer review panels, (x) participate in fishery management plan development or evaluation teams, (xi) defends a stock assessment in a court of law, (xii) research and write scientific papers for primary publication, (xiii) attend colleagues' seminars and offer critical review, (xiv) conduct formal, written peer reviews of articles submitted for publication in scientific journals, (xv) participate on committees to advance approaches to stock assessment and fisheries management, (xvi) undertake training to stay abreast of new methodologies, (xvii) run courses or workshops to train others, (xviii) participate in national and international meetings and conferences to enhance professional development, and (xix) undertake a variable amount of administrative duties depending on supervisory level. With limited exceptions, there is insufficient scope for individual scientists to focus on just one or a few of these activities due to an overall shortage of assessment scientists. A survey of assessment scientists indicated that there is insufficient time to devote to important activities such as research to improve the basis for assessments, professional development, and interactions and cooperative research with national and international peers. The same is likely to be true for individuals involved in data collection, data processing, and data management.

- In fact, staffing needs associated with the production of stock assessments go well beyond stock assessment scientists *per se*, who represent only the "tip of the iceberg." Far greater numbers of staff are needed for deployment in critical data collection activities, such as commercial or recreational catch and effort data, port sampling for biological data, observer programs, and fishery-independent resource surveys. Additional staff are also required to process biological samples (e.g. to determine fish ages from hard structures, construct age-length keys, develop growth curves, construct maturity ogives, and possibly to identify and count eggs and larval fish from ichthyoplankton surveys, and to examine stomach contents), and to enter, audit, integrate, and preprocess data from the myriad of data collection activities.

- The Task Force defined three Tiers of Assessment Excellence, which can be summarized as:

  Tier 1–Improve stock assessments using existing data
  (a) for core species, conduct assessments that are more comprehensive, more thorough, more timely, better quality-controlled, and better communicated;
  (b) for species of currently "unknown" status, mine existing databases of research vessel survey data and/or commercial and recreational statistics for archival information for new analyses to evaluate status determination criteria.
  Tier 2–Elevate stock assessments to new national standards of excellence
  (a) upgrade assessments for core species to at least Level 3 [the Task Force defined six levels at which assessments are conducted, ranging from 0 to 5; Level 3 assessments comprise analytical models in which ages or species are aggregated];
  (b) conduct adequate baseline monitoring for all federally managed species (including rare species).
  Tier 3–Next generation assessments
  (a) assess all federally managed species or species groups at a minimum level of 3, and all core species at a level of 4 or 5 [size, age or stage-structured models, possibly including spatial and seasonal considerations, species associations, and oceanographic effects];
  (b) explicitly incorporate ecosystem considerations such as multispecies interactions and environmental effects, fisheries oceanography, and spatial and seasonal analyses.

- A large part of the report specifies region-by-region program and staffing requirements needed to meet the three Tiers of Assessment Excellence. These are summarized in **Table 8** of the report, which is reproduced here.

- Among other things, the Task Force recommends that NMFS should aggressively pursue a course of action focusing on new budget and staffing initiatives to modernize its data collection and assessment capabilities. At the minimum, NMFS should attempt to bring stock assessment science to at least Tier 2, and should initiate dialog both within house and with the public to determine how far reaching and comprehensive Tier 3 should be. This will require hiring or contracting considerable numbers of additional qualified staff for data collection, data processing, data management, stock assessments, and evaluations of alternative management strategies, to ensure adequate data and analyses on which to base conservation and management decisions, now and into the future.

- It is also recommended that in order to develop more comprehensive and integrated future budget initiatives geared towards modernizing fisheries assessments and management, NMFS should prepare an umbrella plan that integrates all relevant existing documents on these themes; for example, the current Stock Assessment Improvement Plan, the NOAA Fisheries Data Acquisition Plan (**Appendix 3**), the

Table 8

Total Full-Time Equivalents (FTEs) required to meet the three Tiers of Assessment Excellence for each Science Center and all Centers combined. Estimated current FTEs include in-house staff, contractors such as observers, and "other," which includes state government biologists, and employees or contractors associated with various regional, national, and international commissions. Numbers should be cumulated across tiers.

	Current							
Center	In-house	Contract	Other	Tier 1	Tier 2	Tier 1+2	Tier 3	All Tiers
NEFSC	123	49	16	18	43	61	25	86
SEFSC	71	30	46	14	42	56	39	95
SWFSC	80	15	26+	27	60	87	66	153
NWFSC	18	33	59	13	74	87	39	126
AFSC	154	122	54	31	66	97	51	148
Summed FTEs	446	249	201	103	285	388	220	608
$$ (FTE x $150K)				$15,450K	$42,750K	$58,200K	$33,000K	$91,200K

NMFS Strategic Plan for Fisheries Research (NMFS 2001b), the Proposed Implementation of a Fishing Vessel Registration and Fisheries Information Management System (**Appendix 8**), the NMFS Bycatch Plan (**Appendix 9**), the National Observer Program (**Appendix 10**), the Social Sciences Plan (**Appendix 11**), the Advanced Technologies Working Group (**Appendix 12**), and relevant fisheries oceanography initiatives (e.g. **Appendix 13**).

- In order to make substantial progress towards collecting the data needed to improve stock assessments, particularly next generation assessments, it is essential that NMFS continue to foster partnerships and cooperative research programs with other Federal agencies, state agencies, private foundations, universities, commercial and recreational fishing organizations and individuals, environmental groups, and others with a vested interest in collecting similar types of data, although often for different purposes. Programs involving cooperative research with the fishing industry should continue to be developed and expanded as mechanisms for providing data relevant to improving the quality of stock assessments.

SAIP Executive Summary References

NMFS. 1999a. Report to Congress on the status of fisheries of the United States. National Marine Fisheries Service, Silver Spring, MD, 104 p.

NMFS. 2001b. NMFS strategic plan for fisheries research. National Marine Fisheries Service, Silver Spring, MD, 88 p.

NRC. 1998a. Improving fish stock assessments. National Academy Press, Washington, DC, 177 p.

Appendix 4: Summary of the Fish Stock Sustainability Index (FSSI) and List of FSSI Stocks

The FSSI is a Government Performance and Results Act level performance measure for the sustainability of 230 U.S. commercial and recreational fish stocks or stock complexes. This stock index provides an overall indicator of the health of the nation's most important commercial and recreational fisheries. The FSSI tracks the outcome of increasing knowledge about the status of stocks, managing fish harvest rates, and building and maintaining fish stocks at productive levels. More information about FSSI scoring, as well as individual stock scores, overall FSSI scores, and summary changes are available on the NOAA Sustainable Fisheries website at http://www.nmfs.noaa.gov/sfa/statusoffisheries/SOSmain.htm.

The FSSI is based on a set of 230 priority fish stocks and stock complexes selected for their importance to commercial and recreational fisheries. Criteria for the selection of stocks for the FSSI included: 1) whether they were "major" stocks (i.e. annual landings greater than 200,000 lb); 2) whether they were overfished or subject to overfishing; 3) whether they had stock assessments scheduled in the near future; 4) whether they had previously been identified as important; and 5) other factors deemed important by the responsible Regional Office as appropriate. These stocks represent about 90% of all commercial and landings in the United States.

Jurisdiction	FMP	Stock Name
Pacific Islands Fisheries Science Center		
WPFMC	Bottomfish and Seamount Groundfish Fisheries of the Western Pacific Region	American Samoa Bottomfish Multi-species Complex
		Guam Bottomfish Multi-species Complex
		Hancock Seamount Groundfish Complex
		Hawaiian Archipelago Bottomfish Multi-species Complex
WPFMC	Coral Reef Ecosystem of the Western Pacific Region	Hawaiian Archipelago Coral Reef Ecosystem Multi-species Complex
		Bigeye scad - Hawaiian Archipelago
		Mackerel scad - Hawaiian Archipelago
WPFMC	Pelagic Fisheries of the Western Pacific Region	Albacore - South Pacific
		Indo-Pacific blue marlin - Pacific
		Kawakawa - Tropical Pacific
		Opah - Pacific
		Shortbill spearfish - Pacific
		Skipjack tuna - Central Western Pacific
		Striped marlin - Central Western Pacific
		Wahoo - Pacific
		Yellowfin tuna - Central Western Pacific
Alaska Fisheries Science Center		
NPFMC	Bering Sea / Aleutian Islands King and Tanner Crabs	Blue king crab - Pribilof Islands
		Blue king crab - Saint Matthews Island
		Golden king crab - Aleutian Islands
		Red king crab - Bristol Bay
		Red king crab - Norton Sound
		Red king crab - Pribilof Islands
		Red king crab - Western Aleutian Islands
		Snow crab - Bering Sea
		Southern Tanner crab - Bering Sea
NPFMC	Groundfish of the Bering Sea and Aleutian Islands Management Area	Alaska plaice - Bering Sea / Aleutian Islands

Jurisdiction	FMP	Stock Name
Alaska Fisheries Science Center (continued)		
NPFMC	Groundfish of the Bering Sea and Aleutian Islands Management Area (continued)	Atka mackerel - Bering Sea / Aleutian Islands
		Bering Sea / Aleutian Islands Arrowtooth Flounder Complex
		Bering Sea / Aleutian Islands Flathead Sole Complex
		Bering Sea / Aleutian Islands Rock Sole Complex
		Greenland halibut - Bering Sea / Aleutian Islands
		Northern rockfish - Bering Sea / Aleutian Islands
		Pacific cod - Bering Sea / Aleutian Islands
		Pacific ocean perch - Bering Sea / Aleutian Islands
		Rougheye rockfish - Bering Sea / Aleutian Islands
		Walleye pollock - Aleutian Islands
		Walleye pollock - Eastern Bering Sea
		Yellowfin sole - Bering Sea / Aleutian Islands
NPFMC	Groundfish of the Bering Sea and Aleutian Islands Management Area / Groundfish of the Gulf of Alaska	Sablefish - Eastern Bering Sea / Aleutian Islands / Gulf of Alaska
NPFMC	Groundfish of the Gulf of Alaska	Arrowtooth flounder - Gulf of Alaska
		Flathead sole - Gulf of Alaska
		Gulf of Alaska Deepwater Flatfish Complex
		Gulf of Alaska Demersal Shelf Rockfish Complex
		Gulf of Alaska Pelagic Shelf Rockfish Complex
		Gulf of Alaska Thornyhead Rockfish Complex
		Northern rockfish - Western / Central Gulf of Alaska
		Pacific cod - Gulf of Alaska
		Pacific ocean perch - Gulf of Alaska
		Rex sole - Gulf of Alaska
		Rougheye rockfish - Gulf of Alaska
		Walleye pollock - Western / Central Gulf of Alaska
Northwest Fisheries Science Center		
PFMC	Pacific Coast Groundfish	Arrowtooth flounder - Pacific Coast
		Bank rockfish - California
		Black rockfish - Northern Pacific Coast
		Blackgill rockfish - Southern California
		Blue rockfish - California
		Bocaccio - Southern Pacific Coast
		Brown rockfish - Pacific Coast
		Cabezon - California
		California scorpionfish - Southern California
		Canary rockfish - Pacific Coast
		Chilipepper - Southern Pacific Coast
		Cowcod - Southern California
		Darkblotched rockfish - Pacific Coast
		Dover sole - Pacific Coast
		English sole - Pacific Coast
		Gopher rockfish - Northern California
		Kelp greenling - Oregon
		Lingcod - Pacific Coast

Jurisdiction	FMP	Stock Name
Northwest Fisheries Science Center (continued)		
PFMC	Pacific Coast Groundfish (continued)	Longnose skate - Pacific Coast
		Longspine thornyhead - Pacific Coast
		Pacific cod - Pacific Coast
		Pacific grenadier - Pacific Coast
		Pacific hake - Pacific Coast
		Pacific ocean perch - Pacific Coast
		Pacific sanddab - Pacific Coast
		Petrale sole - Pacific Coast
		Rex sole - Pacific Coast
		Rougheye rockfish - Pacific Coast
		Sablefish - Pacific Coast
		Sand sole - Pacific Coast
		Shortbelly rockfish - Pacific Coast
		Shortspine thornyhead - Pacific Coast
		Spiny dogfish - Pacific Coast
		Splitnose rockfish - Pacific Coast
		Starry flounder - Pacific Coast
		Vermilion rockfish - California
		Widow rockfish - Pacific Coast
		Yelloweye rockfish - Pacific Coast
		Yellowtail rockfish - Northern Pacific Coast
Southwest Fisheries Science Center		
PFMC	Coastal Pelagic Species	Jack mackerel - Pacific Coast
		Northern anchovy - Northern Pacific Coast
		Northern anchovy - Southern Pacific Coast
		Opalescent inshore squid - Pacific Coast
		Pacific chub mackerel - Pacific Coast
		Pacific sardine - Pacific Coast
PFMC	U.S. West Coast Fisheries for Highly Migratory Species	Skipjack tuna - Eastern Tropical Pacific
		Striped marlin - Eastern Tropical Pacific
		Yellowfin tuna - Eastern Tropical Pacific
Southwest Fisheries Science Center / Pacific Islands Fisheries Science Center		
PFMC / WPFMC	U.S. West Coast Fisheries for Highly Migratory Species / Pelagic Fisheries of the Western Pacific Region	Albacore - North Pacific
		Bigeye tuna - Pacific
		Blue shark - Pacific
		Dolphinfish - Pacific
		Pacific bluefin tuna - Pacific
		Swordfish - North Pacific
Southeast Fisheries Science Center		
SAFMC / GMFMC	Coastal Migratory Pelagic Resources of the Gulf of Mexico and South Atlantic	Cobia - Gulf of Mexico
		King mackerel - Gulf of Mexico
		King mackerel - Southern Atlantic Coast

Jurisdiction	FMP	Stock Name
Southeast Fisheries Science Center (continued)		
SAFMC / GMFMC	Coastal Migratory Pelagic Resources of the Gulf of Mexico and South Atlantic (continued)	Little tunny - Gulf of Mexico
		Spanish mackerel - Gulf of Mexico
		Spanish mackerel - Southern Atlantic Coast
HMS	Consolidated Atlantic Highly Migratory Species	Albacore - North Atlantic
		Atlantic Large Coastal Shark Complex
		Atlantic sharpnose shark - Atlantic
		Atlantic Small Coastal Shark Complex
		Bigeye tuna - Atlantic
		Blacknose shark - Atlantic
		Blacktip shark - Gulf of Mexico
		Blacktip shark - South Atlantic
		Blue marlin - North Atlantic
		Blue shark - Atlantic
		Bluefin tuna - Western Atlantic
		Bonnethead - Atlantic
		Dusky shark - Atlantic
		Finetooth shark - Atlantic
		Porbeagle - Atlantic
		Sailfish - Western Atlantic
		Sandbar shark - Atlantic
		Shortfin mako - Atlantic
		Swordfish - North Atlantic
		White marlin - North Atlantic
		Yellowfin tuna - Western Atlantic
SAFMC / GMFMC	Dolphin and Wahoo Fishery of the Atlantic / Coastal Migratory Pelagic Resources of the Gulf of Mexico and South Atlantic	Dolphinfish - Southern Atlantic Coast / Gulf of Mexico
CFMC	Queen Conch Resources of Puerto Rico and the U.S. Virgin Islands	Queen conch - Caribbean
GMFMC	Red Drum Fishery of the Gulf of Mexico	Red drum - Gulf of Mexico
GMFMC	Reef Fish Resources of the Gulf of Mexico	Black grouper - Gulf of Mexico
		Gag - Gulf of Mexico
		Gray triggerfish - Gulf of Mexico
		Greater amberjack - Gulf of Mexico
		Hogfish - Gulf of Mexico
		Nassau grouper - Gulf of Mexico
		Red grouper - Gulf of Mexico
		Red snapper - Gulf of Mexico
		Snowy grouper - Gulf of Mexico
		Vermilion snapper - Gulf of Mexico
		Yellowedge grouper - Gulf of Mexico
CFMC	Shallow Water Reef Fish Fishery of Puerto Rico and the U.S. Virgin Islands	Caribbean Grouper Unit 1
		Caribbean Grouper Unit 2
		Caribbean Grouper Unit 4
		Caribbean Snapper Unit 1
		Caribbean Snapper Unit 3
		Caribbean Snapper Unit 4

Jurisdiction	FMP	Stock Name
Southeast Fisheries Science Center (continued)		
GMFMC	Shrimp Fishery of the Gulf of Mexico	Brown shrimp - Gulf of Mexico
		Pink shrimp - Gulf of Mexico
		Royal red shrimp - Gulf of Mexico
		White shrimp - Gulf of Mexico
SAFMC	Shrimp Fishery of the South Atlantic Region	Brown rock shrimp - Southern Atlantic Coast
		Brown shrimp - Southern Atlantic Coast
		Pink shrimp - Southern Atlantic Coast
		White shrimp - Southern Atlantic Coast
SAFMC	Snapper-Grouper Fishery of the South Atlantic Region	Black grouper - Southern Atlantic Coast
		Black sea bass - Southern Atlantic Coast
		Gag - Southern Atlantic Coast
		Gray triggerfish - Southern Atlantic Coast
		Greater amberjack - Southern Atlantic Coast
		Hogfish - Southern Atlantic Coast
		Red grouper - Southern Atlantic Coast
		Red porgy - Southern Atlantic Coast
		Red snapper - Southern Atlantic Coast
		Scamp - Southern Atlantic Coast
		Snowy grouper - Southern Atlantic Coast
		Speckled hind - Southern Atlantic Coast
		Tilefish - Southern Atlantic Coast
		Vermilion snapper - Southern Atlantic Coast
		Warsaw grouper - Southern Atlantic Coast
		White grunt - Southern Atlantic Coast
		Wreckfish - Southern Atlantic Coast
SAFMC / GMFMC	Snapper-Grouper Fishery of the South Atlantic Region / Reef Fish Resources of the Gulf of Mexico	Goliath grouper - Southern Atlantic Coast / Gulf of Mexico
		Yellowtail snapper - Southern Atlantic Coast / Gulf of Mexico
CFMC	Spiny Lobster Fishery of Puerto Rico and the U.S. Virgin Islands	Caribbean spiny lobster - Caribbean
SAFMC / GMFMC	Spiny Lobster in the Gulf of Mexico and South Atlantic	Caribbean spiny lobster - Southern Atlantic Coast / Gulf of Mexico
GMFMC	Stone Crab Fishery of the Gulf of Mexico	Stone crabs (*Menippe* species) - Gulf of Mexico
Northeast Fisheries Science Center		
NEFMC	Atlantic Herring	Atlantic herring - Northwestern Atlantic Coast
MAFMC	Atlantic Mackerel, Squid and Butterfish	Atlantic mackerel - Gulf of Maine / Cape Hatteras
		Butterfish - Gulf of Maine / Cape Hatteras
		Longfin inshore squid - Georges Bank / Cape Hatteras
		Northern shortfin squid - Northwestern Atlantic Coast
NEFMC	Atlantic Sea Scallop	Sea scallop - Northwestern Atlantic Coast
MAFMC	Atlantic Surfclam and Ocean Quahog	Atlantic surfclam - Mid-Atlantic Coast
		Ocean quahog - Atlantic Coast
MAFMC	Bluefish	Bluefish - Atlantic Coast
NEFMC	Deep-Sea Red Crab	Red deepsea crab - Northwestern Atlantic
NEFMC / MAFMC	Monkfish	Goosefish - Gulf of Maine / Northern Georges Bank
		Goosefish - Southern Georges Bank / Mid-Atlantic
NEFMC	Northeast Multispecies	Acadian redfish - Gulf of Maine / Georges Bank

Jurisdiction	FMP	Stock Name
Northeast Fisheries Science Center (continued)		
NEFMC	Northeast Multispecies (continued)	American plaice - Gulf of Maine / Georges Bank
		Atlantic cod - Georges Bank
		Atlantic cod - Gulf of Maine
		Atlantic halibut - Northwestern Atlantic Coast
		Haddock - Georges Bank
		Haddock - Gulf of Maine
		Ocean pout - Northwestern Atlantic Coast
		Offshore hake - Northwestern Atlantic Coast
		Pollock - Gulf of Maine / Georges Bank
		Red hake - Gulf of Maine / Northern Georges Bank
		Red hake - Southern Georges Bank / Mid-Atlantic
		Silver hake - Gulf of Maine / Northern Georges Bank
		Silver hake - Southern Georges Bank / Mid-Atlantic
		White hake - Gulf of Maine / Georges Bank
		Windowpane - Gulf of Maine / Georges Bank
		Windowpane - Southern New England / Mid-Atlantic
		Winter flounder - Georges Bank
		Winter flounder - Gulf of Maine
		Winter flounder - Southern New England / Mid-Atlantic
		Witch flounder - Northwestern Atlantic Coast
		Yellowtail flounder - Cape Cod / Gulf of Maine
		Yellowtail flounder - Georges Bank
		Yellowtail flounder - Southern New England / Mid-Atlantic
NEFMC	Northeast Skate Complex	Barndoor skate - Georges Bank / Southern New England
		Clearnose skate - Southern New England / Mid-Atlantic
		Little skate - Georges Bank / Southern New England
		Rosette skate - Southern New England / Mid-Atlantic
		Smooth skate - Gulf of Maine
		Thorny skate - Gulf of Maine
		Winter skate - Georges Bank / Southern New England
NEFMC / MAFMC	Spiny Dogfish	Spiny dogfish - Atlantic Coast
MAFMC	Summer Flounder, Scup and Black Sea Bass	Black sea bass - Mid-Atlantic Coast
		Scup - Atlantic Coast
		Summer flounder - Mid-Atlantic Coast
MAFMC	Tilefish	Tilefish - Mid-Atlantic Coast

Appendix 5: Executive Summary of "A Research Plan—Assessing Ecosystem Impacts of Liquefied Natural Gas Processing Facilities on Marine Resources in the Gulf of Mexico" (SEFSC, 2006)

There are over 40 Liquefied Natural Gas (LNG) processing facilities proposed or in operation in North America, and about half of these are located in the northern Gulf of Mexico (GOM). LNG facilities are being built in response to an increased demand for imported natural gas. The process of converting LNG back into gas requires heat, and seven facilities in coastal waters of the northern GOM propose to use vaporization systems (mainly Open Rack Vaporization or ORVs) that obtain this heat from seawater. Cumulatively, these seven facilities are projected to use over 1 billion gallons of seawater per day to regasify LNG. The use of ORVs is mainly restricted to the GOM, is controversial, and is projected to have adverse ecosystem impacts.

The controversy regarding potential fishery and ecosystem impacts of LNG facilities has focused attention on the paucity of available scientific information needed to understand the effects of such facilities and highlighted the importance of basic scientific information on early life histories of fishery species. Information available from ongoing NOAA research programs and from the scientific literature suggests that the operation of LNG facilities will have adverse impacts on habitats and organisms, including direct mortality of planktonic organisms in entrained water, limited mortality of organisms from impingement on intake screens, discharge of cooled water into the area, and discharge of antifouling agents such as chlorine and chlorine byproducts. Attempts by the SEFSC to assess the magnitude of these impacts, however, have accentuated significant gaps in our databases, programs, and understanding of coastal systems. This research plan was developed to identify information needs, prioritize the problems to be addressed, distinguish between research and monitoring questions, describe the research needed to address information deficiencies, and integrate this information with ongoing research programs.

This Gulf LNG Research Plan will be used to guide the efforts and activities of the SEFSC's research on LNG facility impacts in the northern Gulf of Mexico for the next 5 years (FY 2007-FY 2011). A major focus of the research plan is to obtain a better understanding of the temporal and spatial distribution of eggs and larvae of fishery species in coastal waters by increasing sampling coverage of the SEAMAP program, analyzing samples for decapod crustacean larvae, understanding vertical distribution and diel migration, measuring extrusion through nets, improving our ability to identify eggs and various stages of larvae to species level, and exploring the utility of remote sensing as a means of estimating larval abundance. Other research areas to be emphasized include 1) determining the fate of entrained organisms, 2) measuring growth and natural mortality during early life stages of fishery species, 3) examining the extent of impingement on intake structures and the role of larval swimming speed in avoiding impingement, 4) examining the role of water currents on facility impacts, 5) understanding socioeconomic impacts, 5) assessing cumulative impacts of multiple facilities, and 6) modeling ecosystem of impacts. The Research Plan focuses on the early life history of fishery species and their role in coastal ecosystems. The program will integrate new research with existing research programs and with expected monitoring information from licensed LNG facilities. Over the 5-year period, the program will require about \$5 M per year (total \$25 M) and a minimum of seven FTEs. The results of this research program will greatly benefit resource managers within NOAA and within other management and licensing agencies.

Appendix 6: Habitat-related Programs and Activities

There are many programs, both within and outside of NOAA, with goals and objectives related to marine habitat. A meaningful exchange of information is expected among these efforts and HAIP-based initiatives.

Habitat-related Programs and Activities Within NOAA

- Advanced Sampling Technology Working Group (ASTWG): ASTWG leads efforts to improve the quality of living marine resource assessments through development, evaluation, and implementation of innovative sampling technology. ASTWG activities help NOAA meet increasing demands for accurate, precise, and timely information to protect, restore, and manage coastal and oceanic resources. Advanced sampling technologies include acoustic, optic, and tagging instrumentation and associated software. ASTWG owns several pieces of sampling equipment that are available for NMFS-wide surveys, including a dual-frequency identification sonar (DIDSON), a Fetch AUV, and an EK60 38-kHz deep-water transducer and transceiver. See http://www.st.nmfs.noaa.gov/st7/AdvancedSamplingTechnology.html.

- Center for Operational Oceanographic Products and Services (CO-OPS): CO-OPS provides the national infrastructure, science, and technical expertise to monitor, assess, and distribute tide, current, water level, and other coastal oceanographic products and services. CO-OPS provides operationally sound observations and monitoring capabilities coupled with operational Nowcast Forecast modeling. CO-OPS developed and supports the NOAA Tides and Currents website, which provides a wide variety of coastal oceanographic data to the public. See http://tidesandcurrents.noaa.gov.

- Coastal and Marine Ecological Classification Standard (CMECS): NOAA's Coastal Services Center, in partnership with NatureServe, developed CMECS as a standard ecological classification system that is intended to be universally applicable for coastal and marine systems and complementary to existing wetland and upland systems. CMECS framework accommodates physical, biological, and chemical information to describe a marine habitat type. CMECS structure is designed to support status and trend monitoring, policy development, restoration planning, ecological assessments, and fisheries management at the local and national levels. CMECS uses three components (benthic cover, water column, and geoform) to describe different aspects of the environment. See http://www.csc.noaa.gov/benthic/cmecs/index.html.

- Comparative Analysis of Marine Ecosystem Organization (CAMEO): CAMEO is implemented through a partnership between NMFS and the National Science Foundation's Division of Ocean Sciences. Its purpose is to strengthen the scientific basis for an ecosystem approach to the stewardship of our ocean and living marine resources. The program supports research to understand complex dynamics controlling productivity, behavior, population connectivity, climate variability, and anthropogenic pressures associated with living marine resources and critical habitats. CAMEO research will employ the use of a diverse array of ecosystem models, comparative analyses of managed and unmanaged areas, and ecosystem-scale mapping that can form a basis for future forecasting and decision support. See http://cameo.noaa.gov/.

- Deep-sea Coral Research and Technology Program (DSCRTP): DSCRTP has six goals: 1) to identify existing research on, and known locations of, deep-sea corals; 2) to locate and map locations of deep-sea corals; 3) to monitor activity in locations where deep-sea corals are known or likely to occur, based on the best scientific information available, including methods using underwater or remote sensing technologies; 4) to conduct research on deep-sea corals and related species, and on survey methods; 5) to develop technologies or methods designed to assist fishing industry participants in reducing interactions between fishing gear and deep-sea corals; and 6) to prioritize program activities in areas where deep-sea corals occur, and in areas where scientific modeling or other methods predict deep-sea corals are likely to be present. See http://www.nmfs.noaa.gov/msa2007/deepseacorals.html.

- Fisheries and the Environment (FATE): FATE's mission is to provide information for effective management to mitigate ecological and social impacts of major shifts in productivity of LMR's. The FATE program focuses on: 1) analysis of the response of fish and shellfish to environmental change; 2) development of ecosystem indicators; 3) incorporation of ecosystem indicators in stock assessments; and 4) construction of next generation forecasting models. FATE complements ongoing research activities of several mesoscale process oriented programs, including the North Pacific Research Board's Bering Sea Integrated Ecosystem Research Program, the Alaska Fisheries Science Center's Fisheries Oceanography Coordinated Investigations program, the U.S. Global Ecosystem Dynamics program (Georges Bank, northern Gulf of Alaska, and the California Current), the Ocean Carrying Capacity study (Gulf of Alaska), and the California Cooperative Oceanic Fisheries Investigations program (southern California Bight). See http://fate.nmfs.noaa.gov/.

- Fishery-independent Survey System (FINSS): FINSS is a national-level repository designed to provide trusted and integrated NMFS fishery-independent survey data and associated metadata (including habitat and protected species surveys) through GIS visualization and online access to NMFS' internal and external users. FINSS constitutes three inter-related databases: Historical Survey Inventory Database, Projected At-sea Fleet Requirement Database, and Incidental Protected Species Take Database; it is scheduled to be operational in 2010.

- Integrated Ocean and Coastal Mapping (IOCM): IOCM's goals are to increase efficiency, eliminate duplication, and enhance the use of mapping data sets that are collected for navigation, ocean exploration, coastal and living resource management, hazards preparedness, response and mitigation, habitat assessments, and ocean and coastal modeling efforts. Some of IOCM's current efforts include the establishment of an IOCM Coordination Team and related work groups; development of an IOCM web site; support NOAA Joint Ocean and Coastal Mapping Centers of Excellence; gap analyses to assess needs for technology, training, and data management; and establishment of standards for improved use of mapping data.

- National Centers for Coastal Ocean Science (NCCOS): NCCOS conducts and supports research, monitoring, assessments, and technical assistance to meet NOAA's coastal stewardship and management responsibilities. NCCOS focuses research on five key ecosystem stressors: climate change, extreme natural events, pollution, invasive species, and land and resource use, directed specifically on coral reefs, in estuaries (including the National Estuarine Research Reserve System), National Marine Sanctuaries, and coastal ocean regions. The scientists within NCCOS conduct applied research and manage long-term research projects, which provide a link between laboratory research and coastal management. See http://coastalscience.noaa.gov/about/welcome.html.

- National Geodetic Survey (NGS): NGS is responsible for defining, managing, and providing public access to the National Spatial Reference System, a consistent national coordinate system that is the foundation for mapping and charting. NGS defines the National Shoreline, providing critical baseline data to manage coastal resources. An accurate, consistent, and up-to-date national shoreline can provide storm surge, coastal flooding, and pollution trajectory modeling; land and marine geographic information systems; and environmental analysis and monitoring. NGS also maps the coastal zone and waterways of the U.S. and its possessions. See http://www.ngs.noaa.gov/.

- National Marine Sanctuary Program: The focus of this Program is to recognize, understand, forecast, and respond to natural and human-caused environmental changes within U.S. Sanctuaries. Sanctuary site characterizations are developed on biodiversity, habitats, resources, ecological processes, effects of human activities, and socioeconomic information. Monitoring programs focus on the status and condition of marine life and habitats to detect trends within the sanctuaries. The National Marine Sanctuary Program is partnering with NCCOS to conduct research within sanctuary waters. See http://sanctuaries.noaa.gov/.

- National Oceanographic Data Center (NODC): NODC is a national repository and dissemination facility of publicly available global oceanographic data (extending back over 100 years) of the Earth's changing environment. NODC maintains and updates a national ocean archive with environmental data acquired from domestic and foreign activities and produces products and research from these data, which help monitor global environmental changes. These data include physical, biological and chemical measurements from coastal and deep ocean areas derived from in situ oceanographic observations, satellite remote sensing of the oceans, and ocean model simulations. The National Coastal Data Development Center (NCDDC) is a major component of NODC and provides a coordinated data management system and data discovery mechanism for atmospheric, oceanographic, and terrestrial physical sciences to facilitate sustained economic growth, scientifically sound environmental management, and public safety to the Nation and international community. NCDDC ensures that core data variables for an Integrated Ecosystem Assessment (IEA) are available to scientists in common usage formats via a web-based portal providing timely access to integrated observations data, information, products, and model analyses. See http://www.nodc.noaa.gov/ and http://www.ncddc.noaa.gov/.

- NMFS Office of Science and Technology Enterprise Data Management: F/ST is leading an effort to develop an Enterprise Data Management system for NMFS, with emphasis on standardized metadata collection, management, and distribution.

- NOAA Coastal Services Center (CSC): The CSC works with various branches of NOAA and other Federal agencies to bring information, services, and technology to the nation's coastal resource managers. Data sources include: imagery; land cover; elevation data from LIDAR (light detection and ranging) or IfSAR (interferometric synthetic aperture radar); shallow benthic habitats primarily from aerial photography or multispectral imagery; NOAA Composite Shoreline; and NOAA Shoreline Data. See http://www.csc.noaa.gov/.

- Office of Oceanic and Atmospheric Research (OAR): OAR cooperates with its research partners to explore and investigate ocean habitats and resources, and to look for changes in the oceans due to natural and human activities. OAR is actively engaged in technology development to improve marine measurement and monitoring capabilities, integrated ocean mapping, habitat monitoring and modeling, and ecological observations and forecasting. OAR strives to build a stronger economy through marine products and businesses, such as biotechnology and sustainable aquaculture. OAR administers NOAA research laboratories (i.e. Pacific Marine Environmental Laboratory, Atlantic Oceanographic and Meteorological Laboratory), the National Sea Grant Program, the Office of Exploration and Research, and the cooperative research institutes.

- Office of Coast Survey: Coast Survey is responsible for acquiring hydrographic data in support of NOAA's nautical charting program and producing and maintaining a suite of over 1,000 nautical charts that cover the coastal waters of the United States, the Great Lakes, and some U.S. territories. The Coast Survey Development Laboratory develops and improves cartographic, hydrographic, and oceanographic systems, helping to provide products and services in support safe and efficient navigation and the utilization and protection of the coast. Coast Survey also offers an expanded variety of products derived from chart data that are GIS user-friendly for the nonnavigational user group. These data are important for many applications besides charting, such as coastal zone management, modeling of tides and currents, predicting hazardous algal blooms, responding to disasters, and assisting in fisheries research and monitoring. See http://www.nauticalcharts.noaa.gov/.

- Office of Ocean and Coastal Resource Management (OCRM): OCRM provides national leadership, strategic direction and guidance to state and territory coastal programs and estuarine research reserves. The Office oversees six major programs: the National Coastal Zone Management Program; the Coral Reef Conservation Program; the National Estuarine Research Reserve System; the Coastal and Estuarine Land Conservation Program; the National Marine Protected Areas Center; and the Coastal Nonpoint Pollution Control Program. OCRM also partners with the University of New Hampshire to form the Cooperative Institute for Coastal and Estuarine Environmental Technology, a leader in transforming science into practical, innovative tools that coastal resource managers need to address the challenges of development, rising sea levels, pollution, and habitat restoration. See http://coastalmanagement.noaa.gov/.

- Office of Ocean Exploration & Research (OER): OER supports NOAA and National objectives by exploring the Earth's largely unknown oceans for the purpose of discovery and the advancement of knowledge. Built from the merger of NOAA's Undersea Research Program and the Office of Ocean Exploration, OER is poised to build on a rich legacy of undersea exploration, discovery, and research. The four core activities in OER's mission are: 1) interdisciplinary exploration; 2) systematic research in four thematic areas (extreme and unique environments, ecosystems frontiers of the continental shelf, new resources from the sea, and ocean dynamics: episodic events to long-term changes); 3) underwater technology; and 4) education and outreach. In 2008, OER began operation of a dedicated exploration vessel, the *Okeanos Explorer*. See http://explore.noaa.gov/ and http://www.nurp.noaa.gov/index.htm.

- Office of Response and Restoration (OR&R): OR&R protects coastal and marine resources, mitigates threats, reduces harm, and restores ecological function. OR&R's core activities include: 1) scientific support for oil and chemical spill response and damage assessments in coastal waters; 2) evaluating coastal contamination; 3) working with communities to address critical local and regional coastal challenges; and 4) restoring and monitoring coastal and estuarine habitat. OR&R participates in the NOAA's Damage Assessment, Remediation, and Restoration Program (DARRP), a multioffice effort involving the Damage Assessment Center, Office of General Council for Natural Resources, and Restoration Center. DARRP conducts studies to identify the extent of resource injuries, the best methods for restoring those resources, and the type and amount of restoration required; OR&R's Assessment and Restoration Division is responsible for assessing the impact to NOAA trust resources from releases of oil and hazardous materials to achieve the goal of restoration. See http://response.restoration.noaa.gov/ and http://www.darrp.noaa.gov/.

- Sea Grant: Sea Grant is a nationwide network of 32 university-based programs administered through NOAA. The National Sea Grant College Program engages this network of the nation's top universities in conducting scientific research, education, training, and extension projects designed to foster science-based decisions about the use and conservation of our aquatic resources. Under the Ecosystems and Habitats Theme, Sea Grant determines the impacts of coastal pollution and develops innovative approaches to protect these habitats from further degradation as well as to reverse the changes that have occurred. Sea Grant emphasizes the land-sea interface in determining the quality of coastal waters, and provides managers with the scientific and technological tools needed to address regional and local problems. See http://www.seagrant.noaa.gov/.

- U.S. Global Ocean Ecosystem Dynamics (GLOBEC): U.S. GLOBEC is a multidisciplinary research program supported by NMFS, NCCOS, and the National Science Foundation. The program has been designed by oceanographers, fishery scientists, and marine ecologists to understand how climate change and variability will translate into changes in the structure and dynamics of marine ecosystems and in fishery production. U.S. GLOBEC data are available at an allied web site in a standardized format through a distributed data management system. U.S. GLOBEC is a component of the U.S. Global Change Research Program and is linked to worldwide research on this topic through the International GLOBEC Program. See http://www.usglobec.org/.

- U.S. Integrated Ocean Observing System (IOOS): IOOS is a multidisciplinary system designed to enhance our ability to collect, deliver, and use ocean information. The goal is to provide continuous data on our open oceans, coastal waters, and Great Lakes in the formats, rates, and scales required by scientists, managers, businesses, governments, and the public to support research and inform decisions. IOOS is the U.S. contribution to the Global Ocean Observing System, which is designed to improve weather forecasts and climate predictions. IOOS represents a national partnership in which 17 Federal agencies and 11 Regional Associations share responsibility for the design, operation, and improvement of a national network of observations. See http://ioos.noaa.gov/ and http://www.ioc-goos.org.

Habitat-related Programs and Activities Outside of NOAA

U.S. Fish and Wildlife Service (USFWS) Programs and Activities

- Coastal Program: This Program aims to efficiently achieve voluntary habitat conservation, through financial and technical assistance, for the benefit of USFWS Trust Species. The Coastal Program works to avoid species declines by enhancing the agency's efforts within the Nation's coastal areas and securing funding for conservation, including habitat restoration efforts. The Coastal Program integrates all USFWS activities in high priority coastal ecosystems to: 1) identify the most important natural resource problems and solutions; 2) influence the planning and decision-making processes of other agencies and organizations with the Service's living resource capabilities; 3) implement solutions on-the-ground in partnership with others; and 4) instill a stewardship ethic, and catalyze the public to help solve problems, change behaviors, and promote ecologically sound decisions. The Coastal Program provides incentives for voluntary protection of threatened, endangered and other species on private and public lands alike. See http://www.fws.gov/coastal.

- National Fish Habitat Action Plan (NFHAP): NFHAP leverages Federal, state, and privately raised funds to build regional partnerships to address the most important fish habitat problems. The emphasis of NFHAP has been on inland, freshwater systems. Led by USFWS, partners include the several states, the USGS, the National Fish and Wildlife Foundation, fishing and conservation organizations and industry, and, more recently, NMFS. The current NFHAP program took shape over the last several years, marked by the publication of the "Action Plan" in 2006 and the recent release of a draft report, "A Framework for Assessing the Nation's Fish Habitat". The first NFHAP national assessment is scheduled for completion in 2010. See http://www.fishhabitat.org/.

- National Wetland Inventory: USFWS has developed a series of topical maps of wetlands habitats to be used for management, research, policy development, education and planning activities. Digital data can be viewed and downloaded through several methods. A Congressional mandate also requires USFWS to produce wetlands status and trends reports for the nation and to report to the Congress at periodic intervals. See http://www.fws.gov/wetlands/index.html.

Non USFWS Habitat-related Programs, Activities, and Agencies

- Census of Marine Life (COML): The COML is a global network of researchers in more than 80 nations engaged in a 10-year scientific initiative to assess and explain the diversity, distribution, and abundance of life in the oceans. The Census aims to: 1) make a comprehensive global list of all forms of life in the sea and catalog these species in an on-line encyclopedia; 2) produce maps of the territory or range of the species; 3) complete measures of abundance. The world's first comprehensive Census of Marine Life will be released in 2010. In addition to field projects, COML also runs the Ocean Biogeographic Information System (OBIS) that provides expert geo-referenced data and spatial query tools for visualizing relationships among species and their environment. Integrating biological, physical, and chemical oceanographic data from numerous sources, OBIS provides tools to test hypotheses about marine biodiversity and assist research on marine ecosystems. OBIS currently contains more than 8.7 million geo-referenced, accurately identified species records from more than 70 databases that are readily and freely accessible via the internet and require no special software to use. See http://www.coml.org.

- Heinz Center's State of the Nation's Ecosystems Project: The Heinz Center is a nonprofit, nonpartisan institution dedicated to improving the scientific and economic foundation for environmental policy through collaboration among industry, environmental organizations, academia, and government. The goal of the State of the Nation's Ecosystems project is to provide a national perspective on the condition of the nation's ecological assets. Experts have identified key aspects of our Nation's coasts and oceans, fresh waters, forests, farmlands, grasslands and shrub lands, and urban and suburban areas that should be tracked through time to provide a consistent and comprehensive view of trends in each of these ecosystems. See http://www.heinzctr.org/ecosystems/.

- Marine Geoscience Data System (MGDS): MGDS provides access to data portals for the National Science Foundation-supported Ridge 2000 and MARGINS programs, the Antarctic and Southern Ocean Data Synthesis, the Global Multi-resolution Topography Synthesis, and Seismic Reflection Field Data Portal. These portals provide free public access to a wide variety of primarily marine geoscience data collected during expeditions throughout the global oceans. MGDS is also host to the U.S. Antarctic Program Data Coordination Center; 2) GeoMapApp, a data visualization and analysis tool; 3) the Global Multi-Resolution Topography, a continuously updated compilation of seafloor bathymetry integrated with global land topography; and 4) the MGDS MediaBank, which contains high quality images, illustrations, animations and video clips. See http://www.marine-geo.org/.

- Minerals Management Service Offshore Energy and Minerals Management Program (MMS-OEMM): MMS, a bureau in the U.S. Department of the Interior, manages the nation's natural gas, oil and other mineral resources on the outer continental shelf. This includes alternative energy programs (i.e. wind, wave, or ocean current energy) as well as offshore oil and gas leasing in U.S. waters. MMS is responsible for conserving these resources and taking maximum steps to protect the environment. OEMM has an Environmental Division that provides environmental policy guidance, direction, and program oversight with respect to: preparing the 5-year leasing program; carrying out a national Environmental Studies Program; seeing that Congressionally provided grant assistance funds are appropriately distributed and used; evaluating the potential and actual environmental impacts associated with extraction of offshore energy and marine minerals; and ensuring that OEMM policies and industry practices conform to the Nation's environmental policies and laws. The Offshore Program is comprised of three regions: Alaska, Gulf of Mexico, and the Pacific. See http://www.mms.gov/.

- Ocean Observatories Initiative (OOI): OOI is a division of the National Science Foundation's (NSF) Ocean Sciences Program that focuses the science, technology, education, and outreach of an emerging network of ocean observing systems. OOI is the NSF's contribution to IOOS. This science-driven effort will focus on discoveries resulting from new technologies, with sensors measuring physical, chemical, geological, and biological variables in the oceans. Greater knowledge of these variables is vital for improved detection and forecasting of environmental changes and their effects on biodiversity, coastal ecosystems, and climate. See http://www.oceanleadership.org.

- U.S. Geological Survey (USGS): The USGS operates a number of habitat-related programs. Their seafloor mapping and benthic characterization work (http://walrus.wr.usgs.gov/pacmaps/index.html) produces maps and geologic information useful for marine resource management. Projects use water and sediment sampling, bottom video, sidescan sonar, and multibeam sonar data, and develop new methods of integrating and distributing data and benthic characterization and surficial geology maps. The usSeabed Project (http://walrus.wr.usgs.gov/usseabed/) provides information about seafloor characteristics from the beach to the deep sea, and aims to improve the understanding of interactions between land and sea, the effects of river discharge and sea level changes, distributions of benthic flora and fauna, location and type of resources, potential consequences of human activities on the oceans, and other critical issues. See http://www.usgs.gov/.

Regional Habitat-related Programs and Activities

- Atlantic Coastal Cooperative Statistics Program (ACCSP): ACCSP is a cooperative state-Federal program to design, implement, and conduct marine fisheries statistics data collection programs, and to integrate those data into a single data management system that will meet the needs of fishery managers, scientists, and fishermen.

- California Seafloor Mapping Project (CSMP): The CSMP is a state-Federal mapping effort to create a comprehensive coastal and marine geologic and habitat base-map series for the entire California land/sea margin (mean high water out to three nautical miles). CSMP includes: ship-based, high-resolution sonar data collection for unmapped coast; data ground-truthing using video or physical sampling of the seafloor; and production of multisheet folio map sets (1:24,000 scale) of bathymetry, geologic, and habitat interpretation. Partners include the California Ocean Protection Council, California Department of Fish and Game, USGS, NOAA's NMFS and Coastal Services Center, and California State University Monterey Bay.

- Center for Coastal Margin Observation & Prediction (CMOP): CMOP is dedicated to researching the health of the ocean and impact of human activity in the Oregon and Washington coastal margins, where the Columbia River meets the Pacific Ocean. CMOP facilitates interdisciplinary research, technology development, education, and knowledge transfer in order to better understand the physical, chemical, and biological processes regulating river-to-ocean ecosystems. The center studies coastal margins (watersheds, estuaries, plume dynamics, nutrient fluxes, tides, microbial communities, estuary turbidity maximum, and the ocean continental shelf) and is currently developing models that will predict everything from algal blooms to salmon runs and improve the health of our rivers and oceans. The center is a multiinstitutional National Science Foundation Science and Technology Center; partners include several academic and industry partners. See http://www.stccmop.org.

- Gulf of Maine Council on the Marine Environment: This is a U.S.-Canadian partnership of government and nongovernment organizations working to maintain and enhance environmental quality in the Gulf of Maine to allow for sustainable resource use by existing and future generations. The Council organizes conferences and workshops; offers grants and recognition awards; conducts environmental monitoring; provides science translation to management; raises public awareness about the Gulf; and connects people, organizations, and information. Some of the Council's specific projects include the Gulf of Maine Mapping Initiative, the Gulfwatch Monitoring Program, the Regional Habitat Monitoring Data System, and habitat restoration and Action Plan competitive grants programs. See http://www.gulfofmaine.org/.

- Gulf of Mexico Alliance: This partnership among Alabama, Florida, Louisiana, Mississippi, and Texas has the goal to enhance the ecological and economic health of the Gulf of Mexico. Four of six priority issues for the Alliance are related to habitat: water quality; habitat conservation and restoration; ecosystem integration and assessment; and nutrients and nutrient impacts. The Alliance's most recent action plan, released in 2009, sets a course to improve the health of coastal ecosystems and economies of the Gulf in ways that a single entity could not achieve. See http://gulfofmexicoalliance.org/welcome.html.

- Hawaiian Archipelago Marine Ecosystem Research Plan (HAMER): HAMER is a conceptual layout of a place-based, 10-year, ecosystem research initiative dedicated to understanding broad-scale archipelagic ecosystem processes. This collaboration among NMFS, the Hawaii Division of Aquatic Resources, the Papahānaumokuākea Marine National Monument, the University of Hawaii, U.S. Fish & Wildlife Service, and the Western Pacific FMC addresses priority areas of research in the region. HAMER's objective is to have Hawaii serve as a large-scale archipelagic laboratory, comparing biophysical processes in the protected and nearly pristine Northwestern Hawaiian Islands to those of the heavily used main Hawaiian Islands. See http://www.pifsc.noaa.gov/tech/NOAA_Tech_Memo_PIFSC_14.pdf.

- North Pacific Research Board (NPRB): The NPRB was created by Congress in 1997 to recommend marine research initiatives to the U.S. Secretary of Commerce; funds are used to conduct research on fisheries or marine ecosystems of the North Pacific Ocean, Bering Sea, and Arctic Ocean. The NPRB has two major research initiatives, the Bering Sea Integrated Ecosystem Research Project (IERP) and the Gulf of Alaska IERP, with goals to determine effects of environmental and anthropogenic processes on dynamic linkages among trophic levels of fish and fisheries, marine mammals and seabirds. See http://www.nprb.org.

- Pacific Coast Marine Habitat Program: This program was developed and is maintained by Pacific States Marine Fisheries Commission. This public website provides access to geospatial data, much of which was compiled in support of the Pacific Coast Groundfish EFH Environmental Impact Statement (EIS). The site features interactive mapping tool to view various data layers, including access to detailed information about each of the 82 groundfish species, economics, and fishing regulations in marine managed areas. See http://marinehabitat.psmfc.org/index.php.

- Southeast Area Monitoring and Assessment Program (SEAMAP): This cooperative program from the southeastern U.S. has goals to: collect long-term, standardized, fisheries-independent data on the condition of regional LMR's and their environment; plan and evaluate SEAMAP-sponsored activities; operate the SEAMAP Information System for efficient management and timely dissemination of fisheries-independent data and information; identify and describe existing non SEAMAP databases and activities that are of value in fisheries-independent assessments of regional LMR's; and coordinate and document SEAMAP activities, and disseminate programmatic information.

- West Coast Governors' Agreement on Ocean Health: This is a proactive collaboration by the Governors of California, Oregon and Washington to protect and manage the ocean and coastal resources along the entire west coast. The Agreement has set goals of clean coastal waters and beaches; healthy ocean and coastal habitats; effective ecosystem-based management; reduced impacts of offshore development; increased ocean awareness and literacy among the region's citizens; expanded ocean and coastal scientific information, research, and monitoring; and sustainable economic development of coastal communities. Four immediate actions are to reinforce opposition to oil and gas leasing, exploration and development; to secure funding to address the threat of nonpoint source pollution; to develop a Sea Grant Research Plan for the west coast in coordination with the National Sea Grant office, academia, and other institutions; and to request the White House Council on Environmental Quality to facilitate the implementation of the U.S. Ocean Action Plan, to assist the three states in requesting and receiving technical assistance from Federal agencies to address issues of regional significance. See http://www.westcoastoceans.gov/.

Appendix 7: Region-Specific Habitat Science Programs and Staffing Needs to Achieve Tiers of Habitat Assessment Excellence

The Pacific Islands Fisheries Science Center (PIFSC)

The PIFSC's area of responsibility includes a vast expanse (1.7 million square miles) of the western and Central Pacific Ocean supporting a wide range of habitats that include shallow reefs, islands, banks, deep slopes, seamounts, and the oceanic seascape. The region comprises two archipelagos (Hawaii and the Mariana Islands) and parts of four other archipelagos (Samoa, Line Islands, Phoenix Islands, and Marshall Islands), and includes some of the most remote and densely populated islands in the world separated by the international high seas. The fisheries of the region are diverse, ranging from commercial oceanic longline fishermen to individual fishers on remote islands who sell their reef catches at local markets. The culturally diverse fishing communities in this region are a unique challenge to data collection, research, and management. Regional management of the pelagic, insular, and seamount fisheries is conducted by the Western Pacific Fishery Management Council (WPFMC), located in Honolulu, Hawaii.

PIFSC Current Habitat Activities

The PIFSC is responsible for 56 management unit species listed under the jurisdiction of the WPFMC. FMP's include bottomfishes/seamount groundfishes, coral reef ecosystems, crustaceans, pelagics (highly migratory species), and precious corals. No dedicated habitat funds exist for the PIFSC, so all current habitat research is conducted as a byproduct of other activities or the result of piecemeal, opportunistic funding from sources outside of NOAA. Some habitat research has been conducted for pelagic fishes by relating fishery catches and environmental data from satellite tagging studies to the horizontal and vertical stratification in the oceanic seascape. Much of this work has been conducted in conjunction with funding to mitigate sea turtle bycatch, and from support of the Fisheries and Environment (FATE) program (see Appendix 6). In particular, remote sensing has been used effectively to assess oceanic habitats and monitor change.

Steep pinnacles that rise from abyssal depths of the Pacific plate to create islands, reefs, and banks form the insular habitat of the Pacific Islands. Although comprising the minority of habitat in the region (the rest is oceanic), the entire insular ecology is dependent on this small area and it is the most vulnerable to impact from anthropogenic effects of development. External funds from the Coral Reef Conservation Program and NOS have supported diver and tow-board imagery surveys of shallow-water coral reefs. Multibeam mapping of mid-water depths (30-2,500 meters) has been extensive and, along with limited optical validation, has led to preliminary benthic characterizations for the Hawaiian Archipelago, American Samoa, Guam and the Northern Mariana Islands, and the Pacific Remote Island Areas. Cooperative efforts with the University of Hawaii have provided almost complete depth and backscatter data for the deep slope areas of the main Hawaiian Islands. These data have been used to inform the management of commercial bottomfish. No dedicated and dependable funding is available to systematically study the resources of the banks, slope, and subphotic zone. The habitat work conducted in these ecosystems has depended on addressing issues at the intersection with protected species or on making use of ephemeral sources of funds (e.g. National Undersea Research Program [NURP], Ocean Exploration [OE], Cooperative grants). It has not been possible to address NMFS long-term priorities to monitor habitat because all funding for habitat work comes from non NMFS sources.

Recent area closures by Presidential decree have formed National Marine Monuments in the Northwestern Hawaiian Islands, the U.S. Line and Phoenix Islands, the Northern Mariana Islands, and Rose Atoll, which protect both insular and pelagic habitat in the Pacific Islands Region. This introduces new challenges to management and stock assessment. Managed species in archipelagic situations where demersal fishes move among open and close areas can compromise the assumptions made in current stock assessment models. Movement data and an understanding of the species habitat ecology rapidly become more relevant in support of stock assessment efforts. With mounting requests for ecosystem evaluations that discern effects of fishing from other sources of variability, there is a need for a systematic, dependable source of habitat data in the Pacific Islands Region.

PIFSC Staffing Levels Required to Meet the Goals of the Tiers of Excellence

The PIFSC currently has 30 full-time scientists dedicated to habitat issues (Table A7-1). Twenty of those staff (67%) are supported with non NMFS funds (NOS support) that are slated for reduction to an undetermined level in 2010. This is a critical consideration for projections of habitat staff to meet the goals of the three Tiers of Excellence in the HAIP. If coral funding levels are maintained, the need for habitat staff could be moderate; if, however, the PIFSC loses NOS coral funding, the need for habitat staff will be much higher. Table A7-1 reflects

Table A7-1

Number of additional staff (full-time equivalents) required to meet the three Tiers of Excellence by type of activity for the Pacific Islands Fisheries Science Center. Number of current staff in each category is an estimate and/or composite developed from survey responses (e.g. 20 staff spending 20% of their time on habitat activities would equate to four full-time staff). Estimated numbers of staff include permanent employees, contractors, and students. Grey cells indicate that an activity did not apply in a particular tier, according to the questionnaire.

Activity	Current	Tier 1	Tier 2	Tiers 1+2	Tier 3	All Tiers
Collect habitat-related data	15	15	5	20	20	40
Process and convert raw habitat data into usable products	5	5	2	7	10	17
Produce habitat-specific assessments	5	2	5	7		7
Determine habitat-specific vital rates over time					20	20
Refine existing habitat-related survey methods/tools and develop new ones	2					
Refine existing population models and develop new habitat-related ones	2					
Incorporate habitat and ecosystem information into stock assessments at SAIP Tier 3					5	5
Refine existing habitat and ecosystem models and develop new ones			2	2	4	6
Develop improved habitat risk assessments					3	3
Communicate improved assessment results and conduct other follow-up work	1	0	1	1	1	2
Total	30	22	15	37	63	100

the number of staff needed in the event that the coral funds are not renewed. The order that activities within the three tiers are conducted depends on the specific context of the research, and circumstances could involve addressing aspects of the three tiers simultaneously.

Tier 1: Identify Habitats for All Life Stages

As discussed in the above section, staff projections for Tier 1 habitat assessments could range between and two and 22 full-time staff depending on the level of continued support from funds outside the Center. That uncertainty aside, Tier 1 should require a minimal increase in staff and a source of funds to conduct operations and improve sampling infrastructure. The initial focus would be on managed species, particularly early life stages that have not yet had their habitat described. Emphasis would be on ecosystems, which would set the groundwork to launch Tier 2 objectives.

Tier 2: Assess Spatial Extent and Temporal Variability of Habitats

Tier 2 will require a considerable increase in staff and more resources to understand the distribution and natural variability by habitat type for managed species and their ecosystem. Tier 2 will make greater use of technology to improve observational capability in between periodic assessments. Research in this tier would seek to understand seasonal and inter-annual aspects of habitat use by managed species and the wider community. Tier 2 findings should greatly refine the current broad definitions of EFH and improve the designation of HAPC's.

Tier 3: Role of Habitats in Growth, Reproduction, and Survival by Life Stage

Successful completion of Tier 1 and Tier 2 will provide the basis for the type and extent of habitat research conducted in Tier 3. This research will be focused on ecosystem interactions and have greater attention to the role of inter-specific competition in the growth, reproduction and survival of marine resources. This research will involve experimental manipulations and other more resolved approaches not used in the earlier tiers. As the work in Tier 3 is dependent on knowing the findings of the Tier 1 and Tier 2, detailed descriptions are not possible.

The Alaska Fisheries Science Center (AFSC)

The AFSC conducts scientific research in support of management goals of the Alaska Regional Office (AKRO) and the North Pacific FMC, which manage the nation's marine resources in a vast expanse (3.3 million square kilometers of the U.S. EEZ) of the North Pacific Ocean. Alaska's physical immensity and high-latitude geography pose major challenges to conducting fisheries research. Alaska contains more than 70% of the nation's continental shelf habitat, 55,000 kilometers of shoreline, and a highly varied submarine bathymetry owing to the numerous geological and physical processes at work. The marine environment can be divided into three major geographical subregions−the

Gulf of Alaska, the Bering Sea including the Aleutian Island Archipelago, and the Chukchi and Beaufort Seas in the Arctic. The first two subregions support particularly rich fisheries. Alaska thus has diverse and major fisheries resources to manage that provide approximately 60% of all U.S. fisheries production.

The AFSC does not have a habitat assessment program per se, but scientists within several different research programs study habitat as it relates to their specific program disciplines. Only a handful of dedicated full-time scientists are trained to conduct habitat ecological assessments, but others are often retooled to study habitat issues as they emerge and time allows. For example, stock assessment scientists now undertake an ecosystem considerations analysis as part of their yearly stock assessment duties. Ecosystem factors considered in these analyses include effects of fishing and climate, changes in the physical environment, trends in predator and prey abundance, and the temporal and spatial distribution of fisheries bycatch. While the resolution of ecosystem data are generally insufficient to warrant modifications to recommendations on acceptable biological catch, the process has set in motion the framework for a stronger link between ecosystem research and fisheries management (i.e. EBFM). First attempts to include habitat data in fisheries stock assessments include the use of bottom temperature and surface current patterns to predict early life history growth and recruitment for some species.

Provisions of the Magnuson-Stevens Fishery Conservation and Management Act of 1996 fueled the most comprehensive habitat assessments completed in Alaska to date by mandating the identification of EFH and the effects of fishing on marine habitats. Recent global interest in the conservation of deep-sea corals sparked a flurry of habitat assessments in areas of high coral and sponge fisheries bycatch. Findings from those studies helped establish new area closures including HAPC's, and initiated more detailed follow-up studies of those habitats and the ecological benefits they provide. AFSC scientists also conduct research and assessments in nearshore habitats to support National Environmental Planning Act consultations and other Environmental Impact Statement (EIS) requirements of the AKRO, including a massive effort to map Alaska's coastline habitat with Shorezone imagery (a mapping and classification system that specializes in the collection and interpretation of low-altitude aerial imagery of the coastal environment).

In 2006, a Habitat and Ecological Processes Program was established to facilitate Center-wide habitat assessment activities at the AFSC. The Program provides the opportunity for AFSC scientists to competitively attain funding for small (< $150K per year) projects outlined in designated research priorities. Funding is provided by the AKRO (Habitat Conservation Division) and research priorities address current issues of habitat management. Aside from this single source of dedicated habitat research funding, scientists are encouraged to submit requests for funding to outside sources such as the North Pacific Research Board, NURP, and OE.

Center-wide contribution to the completion of two major documents, the "Alaska Groundfish Fisheries – Final Programmatic Supplemental EIS" (NMFS, 2004) and the "EIS for EFH Identification and Conservation in Alaska" (NMFS, 2005b), provided comprehensive inventories of EFH for most of Alaska's 57 FMP stocks and stock complexes (which include multiple species) as well as the effects of the fisheries on EFH. Additionally, Stock Assessment and Fishery Evaluation Reports are updated each year and summarize the best available scientific information on EFH for each stock. Scientists and managers from the Alaska Region recently inventoried habitat data sets and encouraged collaborative use of these data (McConnaughey et al., 2009). Much of the framework is therefore already in place as we move toward EBFM and integrated habitat research. However, our scientists currently face new challenges with respect to the effects of climate change on habitat in Alaska. These include the loss of sea ice, acidification of marine waters, and concomitant shifts in the spatial distribution of species and habitat use, particularly in the northern seas (e.g. Chukchi and Beaufort Seas). While these changes are not unique to Alaska, the changes expected here may be extreme and serve as a sentinel on a global scale. To meet these challenges along with continued human competition for limited marine resources, habitat assessment scientists will need a clear vision of the task ahead and the ability to adopt innovative technologies to complete that task.

AFSC Current Habitat Activities

The AFSC conducts research to support the management of 60 stocks/stock complexes of fish and shellfish managed in four FMP's—the Bering Sea and Aleutian Islands Groundfish FMP, the Bering Sea and Aleutian Islands King and Tanner Crab FMP, the Gulf of Alaska Groundfish FMP, and the Arctic FMP. The latter FMP was implemented in December 2009 and governs commercial fishing for all stocks of finfish, shellfish, and other living marine resources in the Chukchi and Beaufort Seas, except those managed by other authorities (i.e. Pacific salmon and Pacific halibut). The AFSC is also responsible for stewardship of the habitat for these managed fish and crab species in Federal waters. An Alaska High Seas Salmon FMP also exists, but management authority of salmon stocks has been delegated to the State of Alaska by the NPFMC. While the AFSC currently has more than 40 positions dedicated to stock assessment (more than 150 positions if fishery independent surveys and supporting functions and analyses are included), there are only about 17 full-time positions dedicated to study the habitat of those species (Table A7-2); two of these (12%) are temporary contractors. The AFSC has a long history of conducting habitat research and pioneered the use of submersibles to conduct deep-water habitat assessments, but few comprehensive habitat assessments have been conducted in Alaska and have generally been conducted in relatively small geographical areas of high interest. Examples

Table A7-2

Number of additional full-time staff required to meet the three Tiers of Excellence by type of activity for the Alaska Fisheries Science Center. The number of staff in each category does not necessarily reflect the absolute number of individuals involved in these activities, because some individuals may divide their time among several activities. Estimated numbers of staff include permanent employees, contractors, and students. Grey cells indicate that an activity did not apply in a particular tier, according to the questionnaire.

Activity	Current	Tier 1	Tier 2	Tiers 1+2	Tier 3	All Tiers
Collect habitat-related data	12	5	7	12	8	20
Process and convert raw habitat data into usable products	3	3	3	6	3	9
Produce habitat-specific assessments	1	7	2	9		9
Determine habitat-specific vital rates over time					5	5
Refine existing habitat-related survey methods/tools and develop new ones	1					
Refine existing population models and develop new habitat-related ones	0					
Incorporate habitat and ecosystem information into stock assessments at SAIP Tier 3					10	10
Refine existing habitat and ecosystem models and develop new ones			4	4	5	9
Develop improved habitat risk assessments					3	3
Communicate improved assessment results and conduct other follow-up work	0	2	0	2	2	4
Total	17	17	16	33	36	69

include: 1) ongoing habitat-specific density stock assessments for yelloweye rockfish in the eastern Gulf of Alaska (conducted by Alaska Department of Fish and Game biologists); 2) an assessment of red tree coral thickets and associated communities in HAPCs in the eastern Gulf of Alaska; and 3) assessment of coral and sponge garden habitats in the central Aleutian Islands—all habitat variables for these studies were measured in situ via submersible observations.

AFSC Staffing Levels Required to Meet the Goals of the Tiers of Excellence

Tier 1: Identify Habitat for All Life Stages

The AFSC would require a minimum of 17 additional full-time staff to conduct Tier 1 habitat assessments (Table A7-2). New staff will be necessary to inventory existing habitat data (surficial sediment, bathymetry, oceanographic parameters, presence of sedentary invertebrates), integrate with species presence/absence data, and identify habitat data gaps that would be prioritized for future collection. Habitat assessments would be initiated for high priority stocks or geographical areas (e.g. HAPC's).

Tier 2: Assess Spatial Extent and Temporal Variability of Habitats

Tier 2 assessments would require the addition of 16 staff and access to new resources to initiate studies on the temporal variability in habitat use for managed species, to conduct risk assessments for those habitats, and conduct spatially explicit surveys to determine habitat-specific biomass by life stage for those species. Tier 2 assessments will require the use of new advanced technologies to improve observational capability in between periodic assessments (monitoring). Use of these new technologies would require new staff with proper training. Research would seek to understand seasonal and inter-annual aspects of habitat use by managed species and the ecosystems they depend on. Tier 2 findings should greatly refine the current broad definitions of EFH by identifying core use areas and improve the designation of HAPC's.

Tier 3: Role of Habitats in Growth, Reproduction, and Survival by Life Stage

Successful completion of Tier 1 and Tier 2 will provide the basis for designing studies necessary to complete Tier 3 habitat assessments. Tier 3 research will focus on ecosystem-level studies that include multispecies interactions, habitat-specific life cycle models, and the determination of habitat-specific vital rates (growth, survival, and reproduction). These types of studies will provide for the undertaking of IEA's and ultimately EBFM for many of the 60 FMP stocks/stock complexes in Alaska. This research requires the development of novel scientific approaches, the use of state-of-the-art technologies to measure habitat-specific vital rates in the laboratory, and 36 additional staff (including at least ten trained animal physiologists).

The Northwest Fisheries Science Center (NWFSC)

The NWFSC provides scientific and technical support to NMFS as mandated by MSRA and ESA for management and conservation of the Northwest Region's marine and anadromous resources. The NWFSC conducts research in cooperation with other Federal and state agencies and academic institutions within the California Current Large Marine Ecosystem (LME) and Puget Sound, which comprise approximately 800,000 square kilometers. Five divisions, Fishery Resource Analysis and Monitoring, Conservation Biology, Environmental Conservation, Fish Ecology, and Resource Enhancement and Utilization Technologies, conduct applied research to resolve problems that threaten marine resources or that deter their use. Four of the five divisions conduct research on marine habitats of stocks that fall within three FMP's of the PFMC (Pacific Coast Groundfish [over 90 species], Coastal Pelagics [nine species], and Pacific Coast Salmon [three species]). With climate change emerging as an important issue, the NWFSC is also investigating impacts of environmental variability and climate on ecosystem processes that support marine and anadromous resources.

The Fishery Resource Analysis and Monitoring division consists of multidisciplinary teams with expertise in fishery biology and ecology, stock assessment, habitat studies, economics, mathematical modeling, statistics, computer science, and field sampling techniques. Members of this program are stationed at the NWFSC facilities in Seattle, Washington and in Newport, Oregon, with some Groundfish Observer Program staff located in California. The Fishery Resource Analysis and Monitoring division coordinates assessments on FSSI groundfish stocks coastwide as well as conducts assessments on individual stocks. Staff scientists develop models for managing multispecies fisheries; design programs to provide information on the extent and characteristics of bycatch in commercial fisheries, as they look at methods to reduce fisheries bycatch; characterize EFH for key groundfish species; investigate the design, feasibility, function, and value of MPA's; and employ advanced technologies in ongoing and emerging programs (e.g. the use of AUV's in untrawlable habitats).

The Conservation Biology division is responsible for characterizing the major components of biodiversity in living marine resources using the latest genetic and quantitative methods. It also has responsibility for identifying factors that pose risks to these components and the mechanisms that limit natural productivity. The Division's multidisciplinary approach draws on expertise from a broad spectrum of scientific disciplines, including risk analysis, genetics, evolutionary biology, ecology, and population biology.

The Environmental Conservation division investigates the impacts on fishery resources by anthropogenic and natural perturbations caused by habitat alteration, chemical contaminants, and harmful algal blooms. Results are used regionally and nationally to determine scientifically sound approaches for conserving living marine resources, restoring habitat productivity and function, assessing the impacts of toxic substances on the health and safety of fishery resources, and responding to environmental emergencies from the release of toxic materials. The Division integrates laboratory assays and field studies in coastal and marine habitats to determine quantitative relationships between toxic substances and impaired habitat function upon fish, shellfish, and marine mammals.

The Fish Ecology division's role is to understand the complex ecological linkages between commercially and recreationally important marine and anadromous fishery resources of the Pacific Northwest and their habitats. Particular emphasis is placed on investigation of the myriad biotic and abiotic factors that control growth, distribution, and survival of important species and on the processes driving short- and long-term population fluctuations. Division scientists conduct regular surveys of pelagic fishes in coastal waters and use several analytical and statistical approaches to determine optimal habitats for managed species. In particular, juvenile salmon have been examined in relation to mesoscale oceanographic features (river plumes, fronts, eddies) and habitat prediction maps have been produced based on satellite and in situ sampling of broad-scale biophysical variables. Similar analyses have been done for coastal pelagics (anchovy, sardines, and herring), highly migratory species (albacore), and the juvenile pelagic phase of many demersal species. In addition to trawling, noninvasive techniques such as acoustics and LIDAR have been used to characterize fine-scale habitat utilization by pelagic species in relation to oceanographic variables.

The Science Center's developing Ecosystem Science Program within the Conservation Biology Division has a set of research themes that are designed to inform large, system-scale assessments and management of living marine resources. This program will be organized around the general framework outlined by Integrated Ecosystem Assessments (IEA's); encompassing qualitative and quantitative approaches to analyzing the dynamics of natural and human components of ecosystems. Included in the work of the program will be the development of analytical approaches to: 1) identify indicators of system function and thresholds associated with different states; 2) estimate the risk status of key natural and human system indicators and collectively, the system's status; 3) evaluate the individual and cumulative effectiveness of alternative sets of management strategies in changing indicator status; and 4) design and test monitoring and adaptive management approaches to evaluate how natural and human systems respond to strategies.

The NWFSC has maintained an ongoing seafloor mapping collaboration with Oregon State University's Active Tectonics and Seafloor Mapping Laboratory since 2001. The goal of this collaboration is to prioritize seafloor-mapping efforts in the area of the northern California Current. This mapping effort has been linked to similar efforts off California with one result being the first map of structural habitats for the entire California Current LME.

The NWFSC, working with one of its academic partners (Oregon State University), has developed the Pacific Coast Ocean Observing System West Coast Habitat Data Portal to integrate marine geological, geophysical, biological, fisheries, and physical oceanographic data at many scales. This data portal provides direct access to data holdings through custom, interactive-view environments and supports data-discovery tools as well as metadata harvest capabilities. This portal can operate as a decision support tool for research and management activities such as research planning, MPA and hydrokinetic facility site selection, and IEA's.

NWFSC Current Habitat Activities

Currently, about 40 full-time staff (of which 30% are contractors) conduct habitat-related research or provide habitat-related data and information used to support fisheries research and management for Pacific Coast FSSI stocks and salmonids managed under the Pacific Coast Salmon Plan at the NWFSC (Table A7-3). Approximately one-third of these individuals are directly involved in habitat-related data collection. Other habitat-related activities include data processing and database management, production of habitat assessments, refining existing habitat-related survey methods and tools, and developing new ones.

NWFSC Staffing Levels Required to Meet the Goals of the Tiers of Excellence

Tier 1: Identify Habitats for All Life Stages

To meet a level of Tier 1 habitat information, the NWFSC would need 20 additional staff (Table A7-3), which would primarily focus on using existing data to examine the status of the current habitat knowledge for Pacific Coast FSSI stocks and salmonids. Ten researchers will be needed to compile habitat-related data and process and convert raw habitat data into usable products. This initial Tier 1 step will require integration into database and GIS information systems. Three additional staff will initiate incorporation of existing habitat-related data into ongoing stock assessments. Lastly, two additional staff will develop a plan for producing Tier 2 and Tier 3 habitat assessments.

Tier 2: Assess Spatial Extent and Temporal Variability of Habitats

To meet a level of Tier 2 habitat information, the NWFSC would need 44 new positions, in addition to the 20 staff necessary to reach Tier 1 (Table A7-3). The staff requirements for Tier 2 reflect needs for groundfishes and salmonids. The majority of new staff (30) would be focused on the collection of habitat data, including seafloor mapping with NWFSC academic partners, and expanded biological surveys in both trawlable and untrawlable habitats using bioacoustics, ROV's, and AUV's. The increase would be sufficient to produce habitat maps for the majority of FSSI and salmonid FMP stocks by life stage as well as accurate descriptions of annual and seasonal variability in fish

Table A7-3

Number of additional full-time staff required to meet the three Tiers of Excellence by type of activity for the Northwest Fisheries Science Center. Number of staff in each category does not necessarily reflect the absolute number of individuals involved in these activities, because some individuals may divide their time among several activities. Estimated numbers of staff include permanent employees, contractors, and students. Grey cells indicate that an activity did not apply in a particular tier, according to the questionnaire.

Activity	Current	Tier 1	Tier 2	Tiers 1+2	Tier 3	All Tiers
Collect habitat-related data	15	4	20	**24**	11	35
Process and convert raw habitat data into usable products	6	6	10	**16**	8	24
Produce habitat-specific assessments	4	7	7	**14**		14
Determine habitat-specific vital rates over time					8	8
Refine existing habitat-related survey methods/tools and develop new ones	5					
Refine existing population models and develop new habitat-related ones	5					
Incorporate habitat and ecosystem information into stock assessments at SAIP Tier 3					5	5
Refine existing habitat and ecosystem models and develop new ones			5	**5**	5	10
Develop improved habitat risk assessments					4	4
Communicate improved assessment results and conduct other follow-up work	5	3	2	**5**	3	8
Total	**40**	**20**	**44**	**64**	**44**	**108**

habitat use. Another major difference in staffing between Tier 1 and Tier 2 is the addition of five individuals to the NWFSC's compliment of modelers to support the refinement of existing habitat and ecosystem models and the development of new ones. The total number of staff needed to meet Tier 1 and Tier 2 criteria is 64—more than a doubling over current levels.

Tier 3: Role of Habitats in Growth, Reproduction, and Survival by Life Stage

To meet a level of Tier 3 habitat information, the NWFSC would need an additional 44 staff (Table A7-3). As with Tier 1 and Tier 2, nearly half of these additional staff would be dedicated to habitat-related data collection and processing habitat data into usable products. Eight new staff would be needed to determine habitat-specific vital rates (age-specific rates of growth, mortality, and reproduction) of species for use in stock assessment models and other applications. Tier 3 also requires the addition of staff to incorporate habitat and ecosystem information into stock assessments at the SAIP Tier 3 level, and to develop improved risk assessments (nine individuals). Further refinement of existing and new habitat and ecosystem models will require five additional staff over the five necessary to reach Tier 2, resulting in an overall increase in the assessment and ecosystem modeling component to 10 individuals.

The total number of additional staff required to meet all Tiers of Excellence is 108, a 270% increase over the current 40 full-time staff conducting habitat-related research or providing habitat-related data and information.

Southwest Fisheries Science Center (SWFSC)

The SWFSC provides both scientific and technical information in support of the management goals of NMFS and the PFMC. SWFSC staff conducts scientific research in the freshwater and marine environments of California, as well as in parts of the Antarctic, Mexico, and open-ocean international waters. Some of this research is carried out in cooperation with the NWFSC as well as the State of California.

The Southwest Region is part of the California Current LME, and comprises five general habitat categories: freshwater streams and rivers; bays and estuaries (e.g. mudflats, marshes, seagrass beds, deep channels); the coastal continental shelf extending from the intertidal (e.g. sandy beaches and rocky shores) to 200 meter depth (e.g. rock pinnacles and offshore banks); benthic habitats of the offshore continental slope from 200 to over 1,000 meter depth (e.g. extensive submarine canyons and seamounts); and the oceanic system of pelagic habitats dominated by the California Current. This region represents one of the major coastal upwelling areas of the world, which supports high densities of forage for diverse assemblages of marine species. Fisheries in this region also are diverse and include the use of commercial trawl nets, hook-and-line gear, purse seines, gillnets, and traps, as well as recreational hook-and-line gear from commercial passenger fishing vessels, private skiffs, beach, and jetty, and spear fishing.

Most, if not all, of California's coastal ecosystem has been dramatically altered by intense, continuous recreational and commercial fishing beginning at least as far back as the 1940's and by increased population growth and coastal development. These human-induced changes are superimposed on natural, but unpredictable, environmental variability caused by large-scale ocean climate phenomena. All of this makes it challenging to identify and understand changes in coastal habitats. Southwest salmon habitat, for example, contains the most anthropogenically-impacted rivers in the country, and yet they support over 80% of the Oregon-California Chinook salmon fishery (averaging just over one-half million fish). Habitat restoration to date has proceeded in a piecemeal fashion that may have contributed to the major declines in the 2008-09 salmon fisheries. Useful scientific advice on what would be the most effective habitat restoration activities is badly needed. Other current management challenges and concerns include damage to seafloor habitats (including deep-sea coral and sponge communities) due to fishing, effects of climate change (including the ecological, political, and economic consequences of northward shifts in fish distributions with increased ocean temperatures and the implications for trans-national and trans-state allocations), effects of marine protected area management, and invasive species (e.g. the recent invasion of jumbo squid in the California Current Ecosystem).

SWFSC Current Habitat Activities

The SWFSC currently has 33 full-time staff (of which about 45% are contractors supported from a variety of sources both within and external to NMFS) that conduct research on marine habitats of over 110 stocks and species being tracked within the FSSI and/or included in four FMPs (i.e. Coastal Pelagic, Pacific Coast Groundfish, Pacific Coast Salmon, and Highly Migratory) of the PFMC. Most of this effort is focused on collecting habitat data and processing and converting these data into usable products (Table A7-4). Over the last decade, SWFSC researchers also have been refining existing habitat survey methods and tools and developing new ones. SWFSC habitat research is designed to effectively respond to the MSRA mandates to characterize and protect EFH and to improve stock assessments, as well as to understand and predict the effects of climate and environmental change on fish populations and marine ecosystems at global to local scales. The goal is to provide sound scientific information for effective decision-making and ecosystem management.

Table A7-4

Number of additional full-time staff required to meet the three Tiers of Excellence by type of activity for the Southwest Fisheries Science Center. Number of Staff in each category does not necessarily reflect the absolute number of individuals involved in these activities, because some individuals may divide their time among several activities. Estimated numbers of staff include permanent employees, contractors, and students. Grey cells indicate that an activity did not apply in a particular tier, according to the questionnaire.

Activity	Current	Tier 1	Tier 2	Tiers 1+2	Tier 3	All Tiers
Collect habitat-related data	9	2	8	10	8	18
Process and convert raw habitat data into usable products	12	4	4	8	6	14
Produce habitat-specific assessments	0	2	4	6		6
Determine habitat-specific vital rates over time					6	6
Refine existing habitat-related survey methods/tools and develop new ones	7					
Refine existing population models and develop new habitat-related ones	1					
Incorporate habitat and ecosystem information into stock assessments at SAIP Tier 3					6	6
Refine existing habitat and ecosystem models and develop new ones			4	4	4	8
Develop improved habitat risk assessments					2	2
Communicate improved assessment results and conduct other follow-up work	4	2	2	4	2	6
Total	33	10	22	32	34	66

Researchers at the SWFSC are working to predict biological responses of coastal species such as Pacific sardine, chub mackerel, northern anchovy, market squid, and krill to changing environmental conditions in the California Current pelagic ecosystem. Likewise, researchers are relating variation in biotic and abiotic factors of the ocean environment to population dynamics of Chinook and coho salmon, thereby revealing the importance of various aspects of pelagic habitats. Satellite and acoustic tags are being used to identify habitat use by salmonids (Chinook and steelhead trout) and to define hot spots of adult aggregations; long-line surveys are being used to identify nursery areas for migratory species both in the California Current ecosystem (e.g. common thresher shark) and in international waters (e.g. North Pacific albacore tuna). SWFSC environmental data products (e.g. upwelling index; northern oscillation index) provide the oceanographic context for interpreting seasonal and long-term patterns in distribution, abundance, and complex behaviors of several species along the west coast and throughout the North Pacific. In addition, the west coast node of NOAA CoastWatch program is located at the SWFSC and provides timely and relevant satellite-derived environmental products. Many of these environmental data sets have been made readily accessible to other scientists, managers, educators, and the general public.

Other researchers at the SWFSC have been using a variety of survey tools and approaches to improve our assessments of demersal fishes, macro-invertebrates (including deep-sea coral communities and endangered white abalone), and associated seafloor habitats in relatively deep water off central and southern California. Habitat-specific distribution (EFH Level 1 data) and densities (EFH Level 2 data) of juvenile and adult life stages of a few of 90+ species in the Pacific Coast Groundfish FMP have been determined from nonextractive, visual surveys conducted with ROV's, a manned submersible, scuba, laser line scan, and high-definition drop cameras, often coupled with acoustic surveys and seafloor maps of the continental shelf and upper slope off California. These methods have resulted in habitat-specific assemblage analyses on multiple spatial scales; a fishery-independent stock assessment; characterization of distribution and potential ecological impacts of marine debris; and baseline monitoring of MPA's. Some of these data and methods were used in the recent risk assessment and policy development for EFH of groundfishes on the west coast, and are being used in the California-NOAA-USGS Seafloor Mapping Program.

The sustained pursuit of marine fisheries habitat research by the SWFSC has been possible often due to successful partnerships with our academic colleagues and with opportunistic funding from other NOAA offices (e.g. Sea Grant, NURP, OE, and NOS), USGS, state agencies, and private foundations. A comprehensive research program that is directly focused on the ecological value of marine habitats to fishery stocks and on IEA's will require additional NMFS funding.

SWFSC Staffing Levels Required to Meet the Goals of the Tiers of Excellence

Tier 1: Identify Habitats for All Life Stages

Moving to Tier 1 and assessing habitat associations for all life stages of FSSI and FMP stocks using existing data could be achieved with ten additional SWFSC staff members (Table A7-4). Six researchers and database managers will be needed to identify, collect, and integrate existing data sets of various environmental and biological variables over time and space, which are archived by several state, Federal, and international sources. Habitats for most of these stocks have not been assessed or have been inadequately assessed. Two additional staff members will be needed to produce more comprehensive assessments with the data at hand. Identifying gaps in knowledge and prioritizing habitats for further assessment will be a part of these efforts. Two additional technical staff members will be necessary to organize and communicate results among staff scientists, managers, scientific community, and PFMC.

Tier 2: Assess Spatial Extent and Temporal Variability of Habitats

Meeting the objectives of Tier 2 assessments (i.e. to produce habitat maps over the geographic range of all stocks and life stages and to determine their habitat-specific abundances) will require an estimated 22 new positions in addition to the 10 identified in Tier 1 (Table A7-4). At least 12 more staff members will be needed to expand habitat-specific field surveys, as well as to process and convert the raw data into usable products. SWFSC scientists are developing and using advanced technology survey methods and tools such as manned submersibles, ROV, AUV, multibeam acoustics, LIDAR, satellite and acoustic tracking, and airborne thermal videography to assess habitats and associated species on multiple spatial scales. These methods will form the core for fishery-independent data collection and monitoring in Tier 2. Four additional staff will be needed to conduct assessments from these fine-scale data collection efforts. The analyses of data from these advanced technology surveys will lead to better understanding of the natural patterns of habitat variability over time and across space. These patterns, along with associated population processes, will be used to refine existing habitat and ecosystem models and to develop new ones to predict habitat suitability for the various stocks and to improve stock assessments. These models can also be used to investigate initial risk assessments, which will lead to identification and prioritization of habitat and stock restoration, conservation, and preservation activities. Additional staff will also be needed to communicate improved assessments to PFMC and its advisory bodies, as well as to other constituents.

Tier 3: Role of Habitats in Growth, Reproduction, and Survival by Life Stage

Meeting the objectives of Tier 3 assessments will be especially challenging and will require a substantial increase in scientific effort (Table A7-4). Explicit incorporation of habitat and other ecosystem considerations into stock assessments will require the additional effort of 34 new personnel and the interdisciplinary cooperation and facilitation among stock assessment scientists and habitat biologists and ecologists. This effort will require increases in habitat-related data collection and processing, determination of habitat-specific vital rates over time for the different life stages of the stocks, and integrating of these data into population and ecosystem models.

A total of 66 full-time positions, in addition to the current 33 staff positions, will be required to reach the goals of all Tiers of Excellence for habitat research on FSSI and FMP stocks at the SWFSC. As noted elsewhere in this document, the tasks and objectives identified in each of the three tiers are largely interrelated and will lead to improved stock assessments, risk assessments, and IEA's.

Southeast Fisheries Science Center (SEFSC)

The SEFSC provides science to assist in managing 77 FSSI stocks and stock complexes that are distributed over a wide variety of habitats. The SEFSC is based in Miami, Florida with additional laboratories in Beaufort, North Carolina; Panama City, Florida; Pascagoula, Mississippi; and Galveston, Texas. These laboratories and associated offices conduct multidisciplinary research to provide management information supporting three different FMC's (the South Atlantic FMC, Gulf of Mexico FMC, and Caribbean FMC) and International Commission for the Conservation of Atlantic Tunas through NOAA's Highly Migratory Species program. The Southeast Region encompasses three LME's—the Southeast Shelf, the Gulf of Mexico, and the Caribbean Sea. Fisheries in the Region are diverse and range from artisanal traps for fish and crustaceans on coral reefs to open ocean long-lines for highly migratory species and trawls that sweep the muddy bottom of the Gulf of Mexico for shrimp. Commercial bycatch and large recreational fisheries contribute to allocation controversies.

Coastal bottom habitats in this Region include extensive mud and sand bottom, low relief carbonate-based hard bottom, sponge and shell banks, topographic highs, sea grass beds, and coral reefs. Pelagic habitats are characterized by major oceanographic currents (such as the Gulf Stream and the Loop Current), the Mississippi River plume, and extensive mats of floating Sargassum. Many fishery species in the region occupy the waters over the continental shelf as adults but spend early life stages in estuarine nurseries. This ontogenetic linkage connects coastal ecosystems with inshore habitats that are often impacted or threatened by human development of the coast. Common estuarine habitats used by juvenile fishery species include coastal wetlands, seagrass beds, oyster reefs, mangroves, and tidal mudflats; these habitats are highly productive and appear to be important in sustaining fishery productivity. The coastal zone also is influenced by freshwater and nutrient inputs from numerous watersheds, including the Mississippi River drainage area covering 41% of the 48 contiguous United States.

SEFSC Current Habitat Activities

The large number of habitats in the oceanic and coastal regions of the Southeast Region, combined with the number of fishery species, make habitat research a challenge. We have estimated that an equivalent of 47 full-time staff positions (Table A7-5) are currently working on habitat issues related to FSSI/FMP stocks in the SEFSC. Approximately 27% of these are contract employees, and funding for these positions comes from a wide variety of programmatic and reimbursable sources both internal and external to NMFS. The goals and objectives of this habitat research are widely variable, commensurate with the ephemeral nature of these funding sources.

Current habitat research at the SEFSC addresses all three tiers of the HAIP. Maps of coral reef habitats, topographic highs, and other bottom types in coastal waters are being produced using sidescan and multibeam sonar in response to existing and emergent natural and anthropogenic stressors. The abundance and size composition of fishery species is collected and associated with habitat characteristics in many of these research programs. Habitat associations are developed using traditional sampling and video surveys along with hydroacoustic survey techniques, acoustic and popup satellite tagging, DIDSON, and stereo-video cameras. The objectives of this habitat monitoring and research are to identify and define habitats, to elucidate their roles in structuring and maintaining marine communities, to evaluate habitat associations and condition, and to develop science-based practices to conserve and restore critical habitats. Regional threats include habitat damage and change from fishing, hurricanes and storms, climate change and sea level rise, coral bleaching, disease, and biological accumulation and uptake of toxins. More recent habitat issues involve potential threats from invasive species (e.g. lionfish), ocean acidification, the placement of liquid natural gas (LNG) facilities (see Appendix 5), offshore aquaculture impacts, and eutrophication that can lead to harmful algal blooms, hypoxia, and extensive dead zones.

Estuarine habitats in the Southeast Region are highly susceptible to impacts from development and increasing populations along the coast. Thus, research on habitat associations of juvenile fishery species in estuarine nurseries has been emphasized over the last 30 years. For example, some of the earliest studies on the value of seagrass beds were initiated at SEFSC laboratories along with extensive research on estuarine shrimp habitats. Much of this work has been focused on developing techniques to collect quantitative density estimates and to measure habitat-related growth and mortality. An important goal of this research is to link habitats with fishery production, and a variety of modeling approaches have been developed to combine density, growth, and mortality estimates into measures of productivity. Because many estuarine habitats are being lost to coastal development, techniques to restore functional habitats are being examined. Most recently, fishery production models have been used to develop construction cost: fishery benefit ratios for habitat restoration projects.

SEFSC staff engaged in fishery independent resource surveys for stock assessments have not been considered as habitat research staff in our analyses, but these surveys provide critical information on the spatial distribution of harvested and early life history stages of FSSI stocks needed to produce habitat assessments. The Southeast Area Monitoring and Assessment Program (SEAMAP) is a cooperative state-Federal program for the systematic collection, management, and dissemination of fishery-independent data in the southeastern United States. Currently, limited habitat information is collected in this program due to funding constraints; however, a recent SEAMAP 2006-2010 Manage-

Table A7-5

Number of additional full-time staff required to meet the three Tiers of Excellence by type of activity for the Southeast Fisheries Science Center. Number of staff in each category does not necessarily reflect the absolute number of individuals involved in these activities, because some individuals may divide their time among several activities. Estimated numbers of staff include permanent employees, contractors, and students. Grey cells indicate that an activity did not apply in a particular tier, according to the questionnaire.

Activity	Current	Tier 1	Tier 2	Tiers 1+2	Tier 3	All Tiers
Collect habitat-related data	21	4	21	**24**	10	34
Process and convert raw habitat data into usable products	10	13	10	**23**	10	33
Produce habitat-specific assessments	5	6	10	**16**		16
Determine habitat-specific vital rates over time					10	10
Refine existing habitat-related survey methods/tools and develop new ones	3					
Refine existing population models and develop new habitat-related ones	4					
Incorporate habitat and ecosystem information into stock assessments at SAIP Tier 3					10	10
Refine existing habitat and ecosystem models and develop new ones			10	**10**	5	15
Develop improved habitat risk assessments					5	5
Communicate improved assessment results and conduct other follow-up work	4	1	5	**6**	5	11
Total	**47**	**24**	**55**	**79**	**55**	**134**

ment Plan has proposed an expansion of this program to provide habitat information along with increased temporal and spatial coverage of sampling. The value of SEAMAP ichthyoplankton data was recently highlighted when NMFS assessed the potential impacts of offshore LNG processing facilities (Appendix 5).

An extensive body of research has been developed on habitat use and value in the Southeast Region, but much of this work has been funded by other state and Federal resource agencies working cooperatively with NOAA and universities. A strong coordinated effort is needed with a strategic plan to develop the dedicated research necessary to link habitat ecology and stock assessments using an ecosystem approach. This link is a critical requirement for EBFM.

SEFSC Staffing Levels Required to Meet the Goals of the Tiers of Excellence

We emphasize in the following discussion of staff requirements to reach the three Tiers of Excellence, as outlined in the HAIP, that these tasks should not be accomplished sequentially. For some species and life stages, we have information on habitat associations and also have measured habitat-related growth and mortality rates. These research programs need to progress into ecosystem modeling and incorporation of habitat parameters into stock assessments. Examples of success in this regard are needed to prove that proposed approaches are realistically feasible.

Tier 1: Identify Habitats for All Life Stages

To reach Tier 1 and assess habitat associations for stocks using existing data, we estimate that an additional 24 full-time staff will be needed (Table A7-5). Two full-time staff (a data manager and GIS expert) at each of the five laboratories would be tasked with collecting and organizing the available data on habitat and stock distributions and associations. We will build preliminary life tables for all FSSI stocks; these tables will identify life stages and describe available information on spatial and temporal distributions. Available information on growth, mortality, and reproduction rates also will be identified in relation to habitats. A Center-based coordinator would oversee an additional staff member at each lab (a total of six new staff) to begin developing habitat assessments for different stocks. Gear specialists (four new staff) and system modelers (three new staff) will be used to plan approaches to collect new quantitative abundance data and use it in habitat assessments. A technical writer would be supported to assist in developing technical reports.

Tier 2: Assess Spatial Extent and Temporal Variability of Habitats

Tier 2 research and monitoring are needed to upgrade habitat assessments to a minimally acceptable level. Increased efforts to collect habitat-related abundance data would be supported by 20 staff (an average of four per laboratory; Table A7-5). They would support the expansion of fishery independent resource surveys such as SEAMAP by increasing the geographic range of sampling and temporal coverage (particularly for early life history stages) and expanding the collection of associated data on habitat characteristics. A particular focus also will be placed on collecting abundance data for reef fishes to better assess habitat associations. The collection of data on habitat distributions will be increased and supported by data managers and GIS specialists (five new staff). At each laboratory, staff will be added (a total of 30 new staff) to produce habitat assessments, refine and develop habitat-related survey methods and tools, refine and develop habitat-related population and ecosystem models, and communicate habitat assessment results to FMC's and other constituents.

Tier 3: Role of Habitats in Growth, Reproduction, and Survival by Life Stage

Tier 3 research is most difficult to plan. This work involves the measurement of growth, mortality, and reproduction for different life stages of FSSI stocks in relation to habitat characteristics and the incorporation of this information on vital rates into stock assessments and integrated ecosystem assessments. We are tentatively estimating an additional 55 staff will be needed to work on these problems, with their efforts focused on the collection of habitat related vital rates and population and ecosystem modeling. We will improve our ability to age all species (including crustaceans) in different life stages in order to measure vital rates. As noted above, some of this work should be conducted on a parallel track with Tier 1 and Tier 2 research.

Northeast Fisheries Science Center (NEFSC)

The NEFSC is responsible for the Northeast Shelf LME, which ranges from Maine to Cape Hatteras, North Carolina. The diversity of habitats ranges from fine clay substrates to cold-water corals. Further, the hydrography of the northeast is complex with major influxes from the warm Gulf Stream from the south as well as cold, often fresher, waters from the Scotian Shelf to the north. This ecosystem is heavily exploited and human activities include commercial and recreational fishing, whale watching, navigation, aquaculture, military operations, pipeline and cable construction, wind and wave energy production, offshore oil and gas development, and mining of sand and gravel.

The NEFSC supports two FMC's (New England and Mid-Atlantic) as well as a consortium of state agencies. Thus, the diversity of habitats, as well as multiple regulatory clients, creates a significant challenge and burden for NMFS scientists that provide much of the habitat data and advice to inform management decisions.

NEFSC Current Habitat Activities

Currently the equivalent of about 54 full-time staff (of which about 15% are contractors) provides the habitat data and information used to support fisheries management and research in the NEFSC (Table A7-6). Roughly two-thirds of these researchers collect habitat data and develop products (e.g. maps, tools, EFH source documents, advice). The rest of these positions are focused largely on habitat assessments, refinement of methods, tools and models, and communications.

NEFSC Staffing Levels Required to Meet the Goals of the Tiers of Excellence

Tier 1: Identify habitats for all life stages

To meet a level of Tier 1 habitat information, the NEFSC would need an additional seven staff (Table A7-6). The main focus of their work would be on tool development and habitat assessment with a smaller enhancement of current communications activities. The addition of these seven positions would particularly facilitate habitat characterization and mapping, development of habitat indices with respect to fish stock status, and provision of information to support management actions such as MPA designation. Including current staff (i.e. 54), 61 NEFSC habitat researchers are needed to meet Tier 1 criteria.

Tier 2: Assess Spatial Extent and Temporal Variability of Habitats

Advancing to Tier 2 habitat information, the NEFSC would need an additional 17 staff. These new positions would particularly facilitate improved habitat characterization and mapping, further development of habitat indices with respect to fish stock status, improve existing models focused on ecosystem and habitat functionality including simulations run in the Atlantis model, energy flow modeling, etc., and improve our understanding of the effects of habitat condition on fish stocks and stock assessment. This would bring the total number of additional staff needed to meet Tier 1 and Tier 2 criteria to 24 (Table A7-6).

Table A7-6

Number of additional full-time staff required to meet the three Tiers of Excellence by type of activity for the Northeast Fisheries Science Center. Number of staff in each category does not necessarily reflect the absolute number of individuals involved in these activities, because some individuals may divide their time among several activities. Estimated numbers of staff include permanent employees, contractors, and students. Grey cells indicate that an activity did not apply in a particular tier, according to the questionnaire.

Activity	Current	Tier 1	Tier 2	Tiers 1+2	Tier 3	All Tiers
Collect habitat-related data	25	0	4	4	15	19
Process and convert raw habitat data into usable products	10	3	3	6	7	13
Produce habitat-specific assessments	7	3	4	7		7
Determine habitat-specific vital rates over time					15	15
Refine existing habitat-related survey methods/tools and develop new ones	5					
Refine existing population models and develop new habitat-related ones	4					
Incorporate habitat and ecosystem information into stock assessments at SAIP Tier 3					5	5
Refine existing habitat and ecosystem models and develop new ones			3	3	5	8
Develop improved habitat risk assessments					5	5
Communicate improved assessment results and conduct other follow-up work	3	1	3	4	4	8
Total	**54**	**7**	**17**	**24**	**56**	**80**

Tier 3: Role of Habitats in Growth, Reproduction, and Survival by Life Stage

To move from Tier 2 to Tier 3 habitat information, the NEFSC would need an additional 56 staff (Table A7-6). Over half of these positions would support data collection, tool development, and particularly the determination of habitat-specific vital rates. About 10 positions will be needed to incorporate habitat and ecosystem information into stock assessments at the SAIP Tier 3 level as well as to improve habitat risk assessments with respect to impacts on managed species. The addition of these 56 positions would particularly facilitate the determination of habitat-specific rates for reproduction, growth, survival and mortality, the refinement of the natural mortality used in most stock assessment models, the provision of other rates that can be used directly by stock assessment experts, the improvement of survey designs and subsequent quality of trawl survey data, the development of regional FMP's, and the implementation of IEA's. This would bring the total number of additional staff needed to meet Tier 1, Tier 2, and Tier 3 criteria to 80. This is an increase of 148% over current levels (i.e. 54); 134 total staff will be needed to fully support a habitat science program at the NEFSC.

Appendix 8: National Priorities (not in any particular order) for Habitat Science Identified in the Our Living Oceans Habitat Report (NMFS, In press) and in "NOAA's Habitat Program: NMFS Strategic Plan 2009-2013" (NMFS, 2009c)

- Enhance biological sampling to characterize distributions and abundances of fish species for all life history stages.
- Characterize benthic habitats and quantify habitat use by fishery species.
- Identify habitat properties that contribute most to survival, growth, and productivity of fishery species.
- Determine habitat properties important in recruitment.
- Identify indicators of ecosystem health.
- Establish baseline conditions, conduct baseline assessments of current threats, and monitor trends in habitat condition.
- Quantify the impacts of threats on coastal and marine habitats, including those from fishing gear, point and nonpoint sources, harmful algal blooms, hypoxia, endocrine disrupting chemicals, and pathogens.
- Predict vulnerability of coastal and marine habitats to new threats.
- Predict the resiliency of habitats to recover from environmental disturbances.
- Evaluate harvest refugia concepts for selected areas and managed species.
- Develop capabilities to detect declining habitat health and strategies to mitigate factors that affect the health of coastal and marine habitats.
- Develop new methods and approaches for restoration of degraded habitats, and monitor and evaluate habitat restoration efforts.
- Improve knowledge of ecosystem processes and services.
- Develop information on the economic value of habitats and functioning ecosystems for supporting fishery and protected resources.
- Identify and estimate the socioeconomic impacts of habitat modifications.
- Communicate habitat science knowledge to fishery management councils and other management agencies.

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