NOAA's Habitat Science and Ecological Forecasting Technical Team's Guidance Document:

Support for NOAA's Habitat Conservation Team and the Ecological Forecasting Roadmap

January 2016

Table of Contents

EXECUTIVE SUMMARY

This document was developed to guide the work of NOAA's Habitat Science & Ecological Forecasting Technical Team's (HS&EF) 5-year coordination, research and assessment portfolio. During the 2016-2020 period, the goal of the team is to coordinate development of a multi-disciplinary capacity for priority habitat/species ecological forecast models that support integrated habitat and living marine resource management. This document defines NOAA priority habitat science needs and couples how data and products from fulfilling those requirements will support ecological forecasts that predict how changes in habitat influences species' distributions, abundances, and productivity. NOAA has a long history in habitat science and ecological modeling, thus the HS&EF technical team serves primarily as a coordination body to leverage resources across NOAA and its partners to advance habitat science and habitat/species ecological forecasts.

The HS&EF team is a cross NOAA line office team that supports two NOAA-wide matrix entities; the NOAA Habitat Conservation Team (NHCT) and NOAA's Ecological Forecast Roadmap (EFR). The NHCT is charged by the NOAA Oceans and Coast Council to advance NOAA's long-term goals for habitat conservation by collaborating on NOAA's habitat activities across the agency and with Federal and non-Federal partners. The EFR provides an operational framework for a NOAA-wide ecological forecasting capability to effectively and efficiently provide dependable, high quality forecast products. The HS&EF team facilitates coordination across NOAA line offices to meet the habitat science and forecasting requirements defined by the NHCT, EFR and other NOAA mandates. The HS&EF team is focusing on understanding how changes in water column environmental conditions (e.g., salinity, temperature) and emergent and benthic habitats, (e.g., corals and seagrasses) impact species' abundance, distribution, and productivity.

Signature Actions

Below is a list of integrated signature actions from the NHCT and EFR that the HS&EF Technical Team is addressing in the near-term. The actions will evolve over time based on NOAA habitat science and ecological forecasting needs.

- Address key science needs for priority habitats, including foundational habitat mapping, characterization and assessment, with emphasis on areas that will support multiple mandates and/or help advance ecosystem services valuation work.
    - Develop models to evaluate the resilience of coastal communities to changes in habitat which results in changes in the ecosystem services available to communities (NOS).
    - Advance NOAA's Coral Reef Watch to identify areas at risk for tropical coral bleaching (NESDIS).

- Conduct NHCT habitat & ecological forecasting efforts in NOAA Habitat Focus Areas where appropriate.
    - Provide ecological assessment and status of resources to provide baseline information to characterize the Choptank Complex HFA (NOS, NMFS).
    - Map benthic habitats based on existing data to support development of species habitat suitability models in Kachemak Bay HFA (NOS, NMFS).
    - Examine how changing watershed patterns alter the flow of nutrients into the Biscayne Bay, and thus alter the habitat provided for fish, protected species, and other organisms in the bay HFA (NMFS, OAR, NOS).
    - Examine how changing water usage in the Biscayne Bay watershed affects the mesohaline habitat used by many juvenile species in the bay HFA (NMFS, OAR).
- Conduct investigations to forecast how changes in pelagic and benthic habitats impact species distributions.
    - Forecast how changes in estuarine water temperature and salinities impact the distribution of early life history stages of key NOAA managed fishery species in the mid-Atlantic region (NOS, OAR, NMFS).
    - Forecast how long-term climate change impacts kelp forest distribution and species associated with the kelp canopy in Southern California (NOS, OAR, NMFS).

INTRODUCTION & BACKGROUND

This document was developed to guide the work of NOAA's Habitat Science & Ecological Forecasting Technical Team's (HS&EF) 5-year coordination, research and assessment portfolio. During the 2016-2020 period, the goal of the team is to coordinate development of a multi-disciplinary capacity for priority habitat/species ecological forecast models that support integrated habitat and living marine resource management. This document defines NOAA priority habitat science needs and couples how data and products from fulfilling those requirements will support ecological forecasts that predict how changes in habitat influences species' distributions, abundances, and productivity. NOAA has a long history in habitat science and ecological modeling, thus the HS&EF technical team serves primarily as a coordination body to leverage resources across NOAA and its partners to advance habitat science and habitat/species ecological forecasts.

The HS&EF team (Appendix I) is a cross NOAA line office team that supports two NOAA-wide matrix entities; the NOAA Habitat Conservation Team (NHCT) and NOAA's Ecological Forecast Roadmap (EFR). The NHCT is charged by the NOAA Oceans and Coast Council to advance NOAA's long-term goals for habitat conservation by collaborating on NOAA's habitat activities across the agency and with Federal and non-Federal partners. The EFR provides an operational framework(a "roadmap") for a NOAA-wide ecological forecasting capability to effectively and efficiently provide dependable, high quality forecast products on a broader sale with consistent delivery. The EFR focuses on four ecological forecasts: 1) Harmful Algal Blooms (HAB), 2) Water Pathogens (e.g., Vibrio), 3) Hypoxia, and 4) Habitat and Species Distributions. The HS&EF team coordinates, supports, and conducts work that primarily addresses the EFR Habitat and Species Distributions forecasts. Appendix II provides a "cross walk" between the science priorities of the NHCT and the EFR goals, and products that the HS&EF team will address over time to advance both matrix programs. Therefore, the HS&EF team facilitates coordination across NOAA line offices to meet the habitat science and forecasting requirements defined by the NHCT, EFR and other NOAA mandates. The HS&EF team is focusing on understanding how changes in water column environmental conditions (e.g., salinity, temperature) and emergent and benthic habitats, (e.g., corals and seagrasses) impact species' abundance, distribution and productivity.

Scope and Scale of HS&EF Efforts

NOAA's 2015 Habitat Policy (NOAA 2015a) defines habitats as coastal rivers and watersheds, estuaries, the Great Lakes, and marine waters; bottom zones through the water column; and an area's physical, geological, chemical, and biological components. Habitat science is the study of relationships among species and their environment. Habitat science is not synonymous with ecosystem science, but habitats form the structural matrix of ecosystems and the work coordinated and conducted by NHCT and EFR significantly contributes to advancing ecosystem-based management within and outside of NOAA.

The USA continues to lose habitat that supports living marine resources (LMRs), and the ecosystem services that they provide at an alarming rate, despite substantial investments in both restoration and regulatory protection. This is in part due to the dearth of detailed scientific information about particular habitats, the specific benefits they provide to human coastal communities, and the species that depend upon them. In accordance with the NOAA 2015 Habitat policy, continued investment in habitat science will allow us to move forward in addressing specifically identified challenge areas for improving habitat conservation, especially in the context of a changing climate. Thus increasing NOAA's capabilities to accurately forecast how habitat modifications impact species distributions, abundances, and productivity is critical to the management of habitat and associated living marine resources (LMRs) in estuarine, coastal, and marine ecosystems.

Efforts to reduce threats to habitats at risk (especially coastal wetlands, seagrasses, coral and oyster reefs) to enhance coastal community resilience and sustainable fisheries through improved socioeconomic valuation of habitat, and to evolve into holistic land- and seascape-scale conservation and management approaches, are made possible when policies are strongly grounded in science. High quality habitat science is critical in order to meet NOAA mandates to manage, protect, and recover LMRs and their habitats, and support resilient coastal community planning and decision-making. The sheer magnitude of societal needs for land- and seascape-scale habitat science cannot be accomplished by NOAA alone or by any other single entity. Meeting these needs requires strategic investments and productive collaborations with partners across multiple agencies and sectors.

Ecological forecasts span a wide range of time and space scales, matching those of the underlying ecosystem processes and management information needs (Fig. 1). NOAA's mission and mandates span a wide range of these scales, from short-term event-scale to long-term climate scenario forecasts. Management information needs are rapidly creating demand for these forecasts at a wide range of time scales, and spatial scales ranging from local (e.g., HAB event impacts on fish species in a bay) to oceanic (e.g., coral bleaching) and global (e.g., climate change scenarios). Often, results must be integrated across scales (e.g., to forecast ecological impacts of global sea level rise on local habitats). Meeting these needs will require careful consideration and integration of data streams and analyses from all NOAA lines.

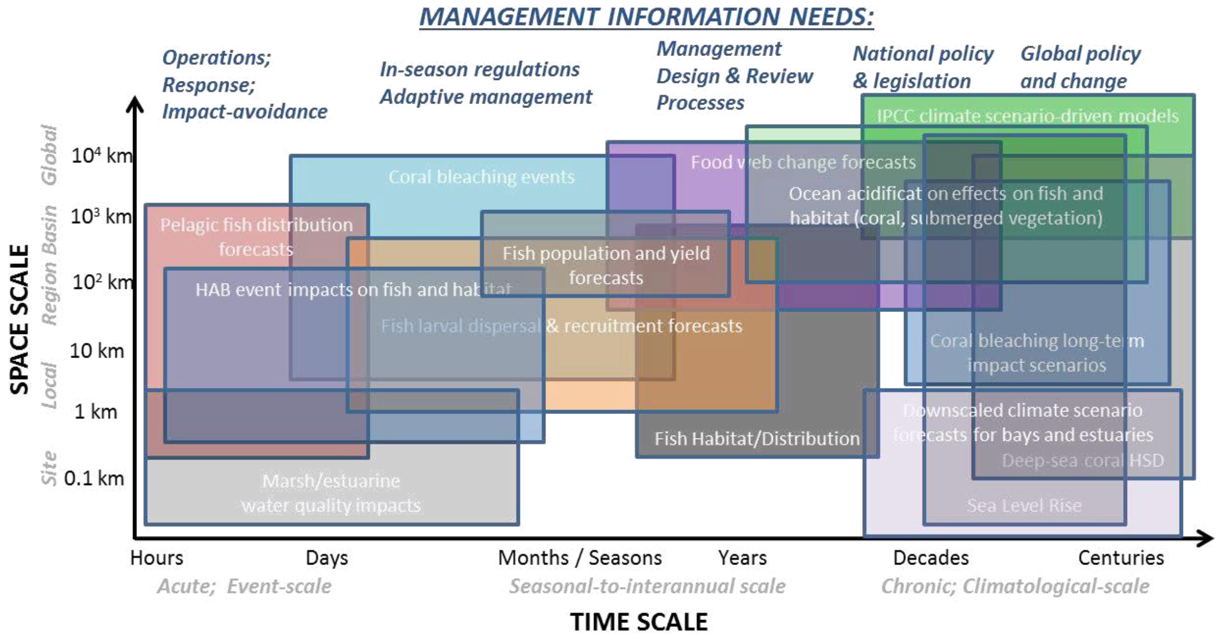

Figure 1. NOAA's management information needs require ecological forecasts of habitat and species' distributions across a wide range of spatial and temporal scales.

Given the scope, scale and complexity of habitat science, ecological forecasting requirements, and limited resources, the HS&EF team is focusing its efforts on the impacts of habitat modifications on species distributions. The HS&EF team is facilitating making maximum use of existing habitat maps, ecological monitoring data, and information on species' habitat affinities as inputs to various ecological forecast models. Efforts are focused on defining and assessing the impacts of changes in key near-shore communities, such as submerged aquatic vegetation (SAVs), corals or other biogenic reefs that provide structure and resources, and offshore pelagic habitats (e.g., changes in water temperatures). Thus, the HS&EF Team will continue to coordinate NOAA investigations that are addressing changes in habitat from natural or anthropogenic phenomenon to facilitate ecological forecasts driven by a range in complexity of species habitat suitability models.

The integrated bio-physical data and models resulting from the team's coordination activities will deliver information to support coastal management needs, including those defined by the NOAA Habitat Focus Areas, NOAA mandates, and regional partners. Through the HS&EF coordination efforts, NOAA habitat science and ecological forecasting products and services have many existing and future user applications including:

- Evaluate the resiliency of habitats to coastal storms and stressors.
- Identify priority habitat restoration areas based on higher probability of success with respect to their ability to recover and/or the resiliency of restored habitats.

- Forecast and understand species' responses to climate changes, including increased water temperature, changes in precipitation effecting flow, ocean acidification, and biogeochemical cycles.

- Forecast loss or gains in ecosystem services provided by habitats and animals from anthropogenic and natural stressors on coastal ecosystems.

- Define ecological "hotspots" for protected and managed species and forecast changes in their distribution and abundance over time based on changes to habitats and management actions.

- Use results of HS&EF forecasts to define and evaluate survey designs that support adaptive sampling approaches to monitor and assess habitat quantity and quality and the distribution and abundance of associated species.

NOAA HABITAT SCIENCE NEEDS

The HS&EF was charged by the NHCT to define and summarize major habitat science needs across NOAA, and identify high priority areas for investigations. A combination of broad and specific programmatic needs was initially identified (Appendix III). The Team synthesized them into four major categories that are essential to more effectively meet NOAA responsibilities including:

I. Foundational Habitat Mapping, Characterization, and Assessment
II. Linking Habitats and LMR Productivity
III. Value of Nature
IV. Climate Change Effects

For each of the four categories, we provide: (1) a description of top priority science needs, (2) examples of the types of collaborative research needed, and (3) benefits of expanding these efforts. All of the science needs share common requirements for efficient dissemination of both data and synthesized information to users, and effective communication with decision makers and the public that NOAA serves. The majority of the science needs defined by the HS&EF team require additional research, monitoring, and assessment activities to obtain data and information to support NOAA habitat priorities consistent with the NOAA Habitat Policy (2015). Many of the activities contained within the four major priority areas directly support the development of habitat science products to facilitate ecological forecast addressing how changes in habitats modulate species distributions and abundances. For example, spatially comprehensive habitat maps that are accurate in thematic content and geospatial location are key products required to develop species' habitat suitability models to predict changes in species distributions over space and time. Thus, the HS&EF team will continue to coordinate NOAA activities across the habitat science priority categories with emphasis on studies that support habitat and species ecological forecasts that ultimately advance ecosystem-based management efforts.

Foundational Habitat Mapping, Characterization, and Assessment

Understanding the current status and trends of key habitat types, as well as the quantity and quality of those habitats that have been lost or gained, constitutes basic foundational scientific information. This information is critical for habitat management (protection, restoration); valuing the benefits of nature (i.e., ecosystem service valuation); meeting NOAA mandates to manage, protect, and recover habitats and associated species; and supporting many other basic science needs within NOAA. Examples of key habitats that are sorely lacking basic mapping information include floodplains, salt marshes, seagrasses, mangroves, deep coral reefs, and other critical habitats. Gaining this knowledge will require investments in data collection across multiple disciplines and scales. Additionally, assessing the status and trends of these habitats, and their differential vulnerabilities and resiliency to climate change and other stressors, is imperative to their conservation and management. Examples activities for the four major needs in the Foundational Habitat Mapping, Characterization, and Assessment category and their importance to ecosystem science are described below. A complete list of needs identified by the HS&EF team is provided in Appendix III, Table 1.

<u>Mapping ecosystems and landscapes</u>

Mapping the distribution, quantity, function, connectivity, and condition of habitats (including geographic, hydrographic, and biological parameters), and measuring the impacts of degradation of their ecosystem processes is necessary for habitat protection, management, restoration, fishery management, the development of recovery plans under the Endangered Species Act (ESA) for listed species, and to fully understand the provisioning of ecosystem benefits linked to ecosystem processes. The NOAA National Ocean Service (NOS) National Centers for Coastal Ocean Science (NCCOS) provides a leading example of habitat mapping. NCCOS and its partners have mapped shallow-water (<30m) coral reef ecosystems in the U.S. Caribbean, Florida, Hawaii, and U.S. Pacific Territories. In addition, NCCOS and other NOAA offices are mapping habitats in depths >30 m for U.S. tropical waters and turbid temperate waters using side-scan and multibeam SONAR technologies. Having access to this information has allowed for the identification of critical habitats that favor aggregations of commercially important fishes, while also establishing baseline information for continued habitat monitoring. This foundational information is supporting ongoing efforts to conserve and restore these sensitive habitats, including habitats for corals that provide Essential Fish Habitat (EFH), and are either ESA listed or being considered for ESA listing.

<u>Assessing the extent, condition, status, and trends of key habitat types</u>

Synthesizing and interpreting the information on spatial extent and quality of different habitat types and their physical, biological, hydrologic, and chemical properties through habitat assessments is critical for effective conservation, sustainability, and management of LMRs and healthy coasts. Work led by the NMFS Northwest Fishery Science Center (NWFSC) in the Columbia River and Skagit River basins in the Pacific Northwest provides a leading example of using mapped habitat information to develop a habitat assessment. To assist with recovery of listed salmon in the Skagit River basin (Figure 2), several parameters (the condition of sediment, floodplain function, and riparian and fish habitat condition) are being included in a landscape-level mapping and analysis effort. This information is being used for protection and definition of EFH, and focusing large habitat restoration efforts in areas of highest potential for recovery of listed anadromous fishes. Accurate information on the extent and health of key habitats is also important for coastal resilience, and for prioritizing restoration efforts, especially in light of the ecosystem services (e.g., protection from extreme events and flooding, carbon sequestration and storage) that these habitats provide to coastal communities and their differential responses to climate change.

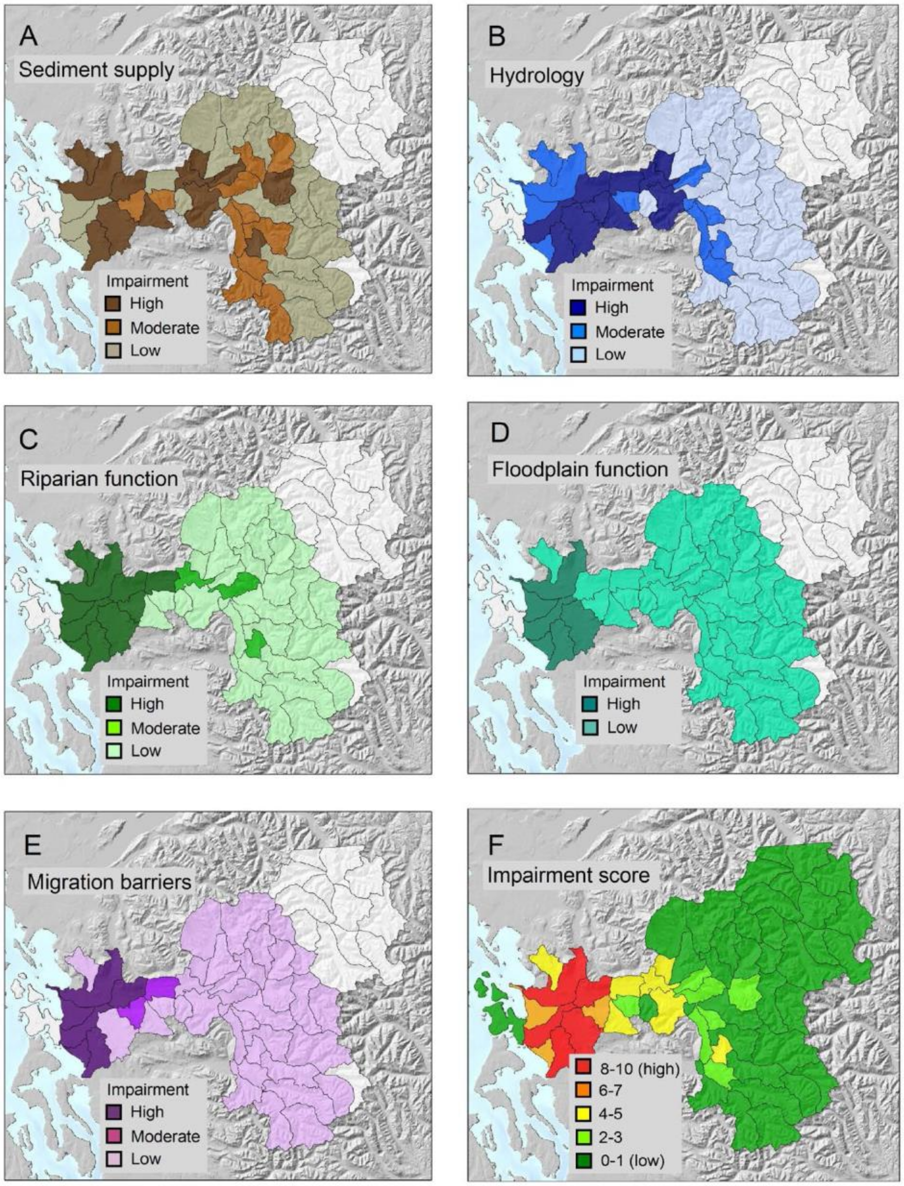

Figure 2. Mapping and assessment of ecosystem and landscape condition across a basin from Skagit River basin, Washington State.

Improving remote sensing technologies for habitat mapping

Current methods for mapping the extent, condition, and connectivity of coastal and offshore habitats are costly, labor intensive, and slow. Remote sensing technologies, such as LIDAR and optical sensors on autonomous underwater vehicles, have the potential to greatly increase the speed and efficiency of habitat data collection in coastal and shelf regions. This is especially critical as detailed, high-resolution bathymetric information is lacking in most areas and some challenges remain in accurately characterizing marine habitats. Translating this information into habitat maps also requires equivalent increases in the speed and efficiency of processing very large quantities of data. The resulting habitat maps can be tied to biological data such that habitat-species affinities at multiple scales can be quantified through development of habitat assessments. For example, LIDAR bathymetric data have been used to successfully predict the diversity and abundance of fish, mangroves, and corals, with great implications for ecosystem-based management.

Gains in the efficiency of developing detailed quantitative habitat maps with species' habitat affinities can lead to a game-changing increase in the availability of habitat information, while enabling the requisite data to be collected and processed at a lower cost based on sampling designs. In turn, this will enable faster, more analytical decision-making processes for prioritizing habitat conservation and restoration actions. In addition, using more efficient mapping technologies to monitor changes in habitat status and trends over time will help improve management.

Improving the accessibility of synthesized habitat data for making management decisions

Making all of the above information readily available for NOAA and partners is critical. In many cases, limited mapping and other research has been conducted by NOAA and partners for regional or local coastal and marine areas. While some of this information has not been disseminated publicly, online platforms such as Marine Cadastre (an integrated marine information system) and the U.S. Integrated Ocean Observing System (IOOS) exist with regularly updated ocean information, including offshore boundaries, infrastructure, human use, and other data sets. An effort to compile habitat information by NOAA and partners is underway by the Pacific Marine and Estuarine Fish Habitat Partnership. A variety of estuarine and nearshore areas have been mapped over the years using different estuarine and nearshore habitat classification systems. This project is compiling and standardizing these geospatial data sets, to produce a single consistent base map of estuarine and nearshore areas along the Pacific Coast. The Coastal Marine Ecological Classification System (CMECS), which has been developed and adopted by NOAA, will be used as the habitat classification for this and other similar efforts.

Linking Habitats and LMR Productivity

Understanding habitat usage by LMRs throughout their life cycles is important for examining the impacts of habitat on population abundance and species productivity. Anthropogenic, natural, and climate-related changes in habitat quantity and quality can affect distribution and abundance of commercially, ecologically, and recreationally important species. Understanding how important habitat areas are used by LMRs, the connections among critical habitats and essential fish habitats, and how these areas contribute to growth and survival allows for more accurate stock assessments and better management of these resources. Examples activities for the three major categories of needs under Linking Habitats and LMR Productivity and their importance to ecosystem science are described below. A complete list of needs identified by the HS&EF is provided in Appendix II, Table 2.

Understanding habitat use by different LMRs and life stages

Information upon habitat use at specific life stages for most LMRs is severely lacking, with only basic information on presence and absence available for many species. Because of this low resolution of information, NMFS's designations of EFH for fishery stocks and Critical Habitat for ESA-listed species, tend to be overly broad and lack specificity. Continued studies are needed that document habitat suitability and identify the characteristics of key habitats that make them important to particular LMRs. In addition, more detailed information is needed to manage and conserve fishery and protected species including: seasonal abundance, current densities, and differential survival among habitat types. Both new research and compilation and analysis of existing data can be used to better understand and map habitat usage.

Effective management requires spatially explicit information on the distribution and abundance of LMR species, coupled with components of their habitat (such as depth and substratum type). Rocky areas on the continental shelf and upper slope off central and southern California are dominated by more than 40 species of rockfishes, some of which have been declared overfished or are in rebuilding plans. Sedentary rockfishes living in high-relief rocky habitats are particularly difficult to survey accurately using traditional methods such as trawls.

These types of studies and products will provide managers, policy makers, and the public with information that can be used in the conservation and management of sustainable marine resources (both the fisheries and associated habitats). Development of models of co-occurring species and associated habitats such as this will have application to ecosystem-based management, providing information needed to manage complex ecological communities. Moreover, a thorough understanding of species habitat usage will be critical for habitat protection and restoration as well as identification of critical and essential habitats (ESA, EFH).

Understanding the relationship between habitat linkages and LMR productivity

While studies into the connections between habitat and its use by LMRs have occurred at varying spatio-temporal scales, for most species there is little high-resolution information regarding the detailed connections between the habitats used by the organisms throughout their life history stages. As a result, models that investigate ecosystem dynamics within and across critical habitats remain data limited. In order to enable comprehensive understanding of the value and function of habitats, much more complete information is needed on the physical and biological connectivity of habitats to complement knowledge of species-habitat affinities across multiple life stages over their biogeographic ranges. This type of information greatly facilitates ecological forecasts across various spatial scales.

Information is needed at multiple scales, ranging from local movements of fish between habitat patches, to the connections between the estuarine and marine habitats occupied by species that migrate between these regions over their life cycles, to the connections between rivers and the ocean that are vital to anadromous species such as salmon. Such information will enable comprehensive species' habitat suitability modeling and examinations of the impacts of both habitat degradation and habitat restoration on LMR productivity. At the local scale, the increased use of acoustic tags implanted in fishes in habitats instrumented with acoustic receivers is providing new information on the fine-scale movement patterns of fish. This yields information on both spatial and temporal habitat affinities, as well as the biological connections among habitats.

Ongoing work on summer flounder at the NOAA Chesapeake Bay Office is an example of research on habitat connectivity at a broad scale. Summer flounder is an economically important species in commercial and recreational fisheries throughout the mid-Atlantic region that is heavily reliant on inshore estuarine habitats for juvenile survival and growth, and uses a broad spectrum of habitats in the Northwest Atlantic (Figure 2). Adults two or more years old spawn as they migrate across the inner continental shelf in the autumn. Because this species and region are data rich, an Atlantis model, incorporating detailed biogeochemical, biological, and ecological processes from the Chesapeake Bay, is being used to explore the sensitivity of juvenile flounder to changes in estuarine habitat. Although the initial focus of the project is the Chesapeake Bay, the results of these modeling efforts will be extrapolated across the entire region occupied by this species. The knowledge gained from conducting these modeling exercises will help illuminate the importance of nearshore habitat for other species as well. Quantitative understanding of habitat connectivity not only provides a basis for defining and refining EFH definitions, but also allows for informed predictions of biological responses to habitat restoration, climate change, loss of sea ice, and habitat fragmentation. Expanding studies on species-habitat linkages and full life cycle analysis will provide critical information for stock management and can inform habitat protection measures (Figure 3).

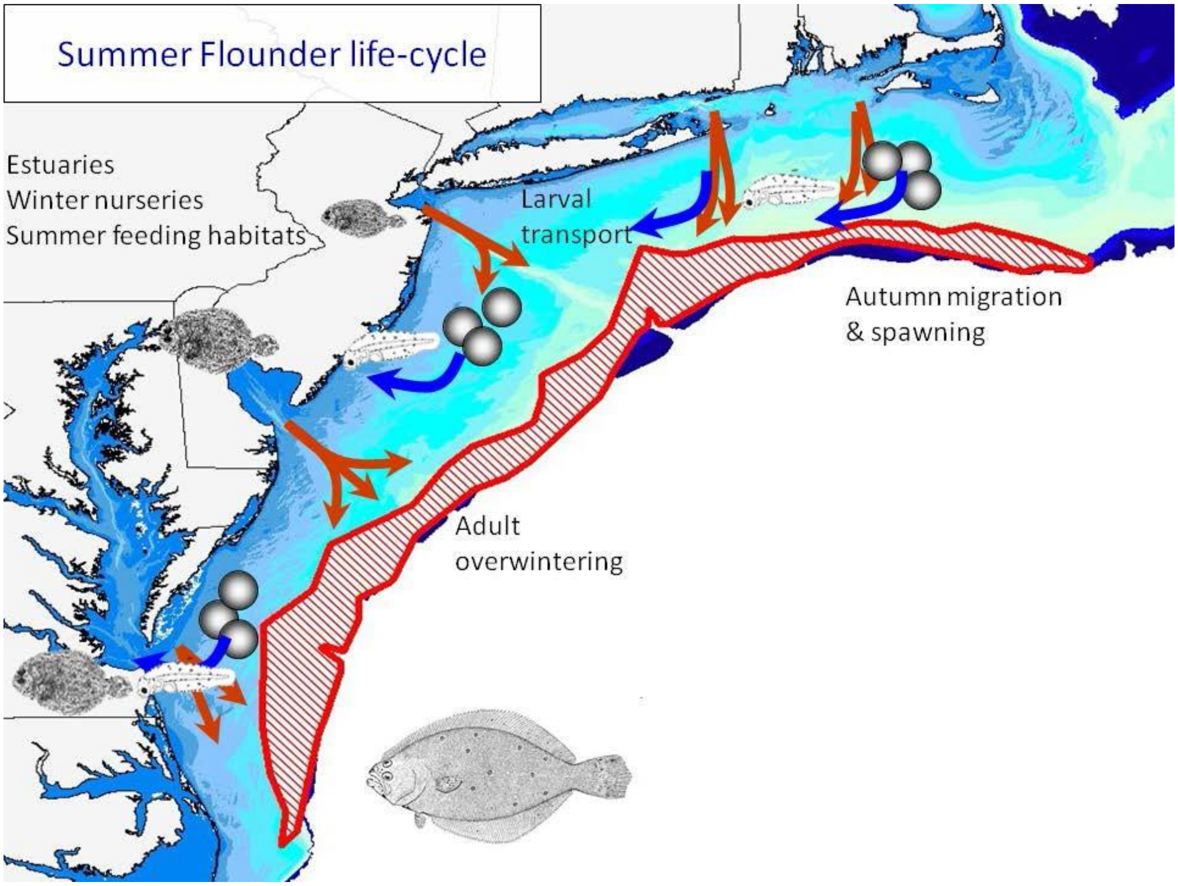

Figure 3. Map of the Mid-Atlantic Bight showing migration of summer flounder through their life history. Red arrows indicate inshore-offshore migration pathway for adults. Blue arrows indicate the hypothesized direction of summer flounder larval drift inshore. Red hatching indicates adult overwintering habitat along the shelf break.

<u>Providing habitat information to support stock assessments</u>

Habitat plays a key role in structuring marine populations, but a lack of detailed scientific information on the effects of habitat on stock productivity largely prevents resource managers from considering the impacts of habitat change when interpreting stock assessments and making decisions on stock status and sustainable fishing. One of the primary goals of the *Habitat Assessment Improvement Plan* is to provide improved habitat science information in support of reducing habitat-related uncertainty in stock assessments and facilitate a greater number of stock assessments that explicitly incorporate habitat information, spatial analyses, and other ecosystem considerations.

A recently completed NMFS assessment for butterfish on the Atlantic Coast is an example of the benefits of considering the effects of habitat in stock assessments. The assessment helped to improve understanding of the stock's population dynamics by developing an external model that estimates butterfish habitat based on ocean temperatures. By accounting for changes in the location of butterfish habitat with changing ocean climate, the external model provided information for use in the stock assessment model to make more accurate estimates of abundance based on the amount of habitat sampled during surveys. The inclusion of this new information resulted in an improved basis for understanding stock history and allowed for the successful estimation of biological reference points and stock status for management, which were unavailable from the previous assessment due to high uncertainty. Most importantly, the improved results allowed managers to substantially increase the butterfish quota for the coming fishing year without jeopardizing the long-term productivity of the stock. This outcome received wide support from a variety of stakeholders involved in the process. Successes like this one demonstrate the need to consider environmental data in measures of stock abundance, especially in the face of climate-induced changes in ocean environments.

Determining the efficacy of habitat conservation and restoration methods

Extensive loss and deterioration of valuable habitats and the vital ecosystem services that they provide have greatly affected fishery resources and the quality of life of coastal inhabitants. Through investment in restoration, there is potential to bring back lost systems and services, and to actively engage local communities in habitat conservation. For decades, projects and management approaches have been designed and implemented to protect and restore the habitats and processes that support the ecological, cultural, and economic value of the coast. However, restoration projects and the selection of Focus Areas under the NOAA Habitat Blueprint (a framework to improve habitat for fisheries, marine life, and coastal communities) must be strongly grounded in scientific understanding of effective methods, and the functioning of ecosystems at multiple spatiotemporal scales. Restoration and protection efforts are also opportunities to understand how ecosystems provide multiple benefits to coastal communities, including storm protection benefits and carbon storage and sequestration.

An example of scientific research on restoration effectiveness that is being used to guide restoration efforts is a continued partnership between NOAA and TNC in the restoration of staghorn (*Acropora cervicornis*) and elkhorn (*A. palmata*) corals. These two ESA-listed species are structurally fundamental to the integrity of reef ecosystems. Continued efforts to reattach broken corals, transplant colonies, and create complex structures for further settlement of larvae have allowed for significant survivorship of out planted corals. These accomplishments were heightened by scientific testing of effective restoration and maintenance techniques, optimal coral propagation times and locations, and ongoing efforts to monitor coral bleaching and disease. Through expansion of this program, there has been increased creation and conservation of reef sites that can provide habitat for fish, sea turtles, lobsters, and other marine invertebrates.

Value of Nature

Healthy habitats are critical for thriving coastal communities, economies, and ecosystems. Beyond the benefits that they provide for fish and wildlife, healthy coastal habitats provide many benefits to society, often referred to as "ecosystem services", including storm protection, pollution removal, climate regulation, nutrient cycling, and many aesthetic, cultural, and recreational values, as well as tourism and jobs. Coastal resource management decisions must account for and promote the social and economic values of conserving healthy habitat, yet we have only begun to quantify ecosystem services provided by coastal and marine habitats. Below are examples for two major categories of needs under Value of Nature. A complete list of needs identified by the NHCT HS&EF team is provided in Appendix 1, Table 3.

<u>Identification and valuation of ecosystem services</u>

A thorough understanding of both the values that functioning habitats provide to society and the impacts of their degradation is necessary to fully realize the benefits of habitat protection and restoration, fisheries management, recovery of ESA-listed species, and climate mitigation and adaptation benefits, including reductions in the vulnerability of coastal communities to extreme events and flooding. Social and economic analysis of fisheries conservation actions on fishing communities is required under National Standard 8 of the Magnuson-Stevens Fishery Conservation and Management Act. Although important, these analyses are not designed to give a complete picture of the ecosystem services provided by habitat. The explicit consideration of biological functions that contribute to ecosystem goods and services is a relatively new concept for NOAA's place-based management, and studies are just beginning to apply this concept with some consistency and regularity. Quantitative values for some of the direct connections between ecological health and societal benefits will play an increasingly important role in place-based management, and there is great potential for a wide range of applications. This field will evolve over time; success will depend on effective communication and the commitment of NOAA and its partners to develop and socialize this capacity.

As these efforts continue to be organized and expanded, there is potential for continued successes, as evidenced by a Natural Capital Project partnership with the World Wildlife Fund and the Belize Coastal Zone Management Authority and Institute. Their project is considered a model for other programs. Using InVEST modeling software, the partners analyzed how ecological processes impact the delivery of natural benefits to society. This study informed marine planning by identifying how different users would be affected by particular spatial plans. Figure 4 shows an example from this project, comparing the impacts of various management options on habitat types and on lobster catch and revenue using InVEST software. The results have been used to produce a coastal zone management plan for the entire Belizean Coast that designates areas for preservation, restoration, development, and other uses.

Efforts by NOAA to value ecosystem services are currently underway. Expanding these efforts to a variety of habitats will be essential for meeting its goals for healthy, resilient coastal communities, sustainable fisheries and recovering protected resources, and habitat protection and management.

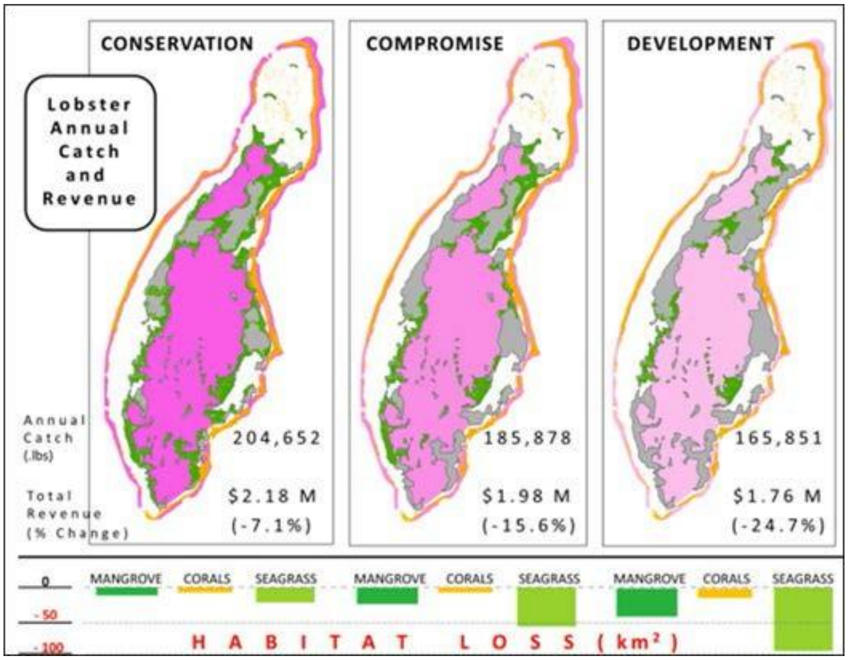

Figure 4. Comparing Zoning Options with InVEST software: Turneffe Atoll, Belize

<u>Advancing the understanding and use of ecosystem services in habitat restoration planning and prioritization</u>

Habitat restoration can provide multiple economic benefits to communities beyond sustaining fisheries, which are often overlooked and rarely valued as part of the decision-making context. Through the use of natural and nature-based approaches, sometimes called green infrastructure, great opportunity exists to protect shorelines and coastal communities from erosion and inundation, improve water quality and habitat for commercial and recreational fish species, create opportunities for recreation and commerce, and foster ecological resilience. Restoration of oyster reefs is occurring in many regions, which may provide added fisheries benefits (e.g., finfish and crab habitat), aquaculture benefits (from oyster harvest), and nitrogen abatement benefits that can improve water quality. Ongoing studies by NCCOS and others into the effectiveness of different natural habitats (e.g., marsh, reef, and mangroves) to stabilize shorelines at varying energy settings will assist in understanding the ecosystem services that they provide. Moreover, it is essential that NOAA take a multi-service perspective when designing and implementing research and restoration projects, keeping in mind that habitat that can provide EFH can also provide key resilience benefits to coastal communities.

Fully incorporating the values of ecosystem services into coastal management decisions would greatly improve resilience of our natural resources and coastal communities over the long-term. Advancing the science needed for improved understanding of the ecological processes and functions that provide ecosystem services and economic valuation of coastal habitats will allow us to provide coastal communities the information needed to make decisions that support both the resilience of natural resources and the communities that depend on them.

Climate Change Effects

Warming, altered precipitation patterns, sea level rise, ocean acidification, and other consequences of climate change have the potential to dramatically alter the quality, quantity, and distribution of shoreline, nearshore, and open water habitats across our rivers, estuaries, coast lines, and oceans. These changes in climate will cause alterations in the distribution and productivity of habitats and the living resources they contain. In turn, they will greatly affect the human activities and infrastructure they support and protect. Therefore, understanding and forecasting the effects of future climate changes on riverine, estuarine, coastal, and offshore habitats is a key requirement for developing effective mitigation and adaptation plans to preserve the portfolio of ecosystem services upon which our nation's coastal economy and coastal communities depend. As coastal communities are dependent on the ability of these habitats to provide ecosystem services, key science to help forecast the impacts of a changing climate will aid in increasing future coastal resiliency. Below are examples for three major categories of scientific needs under Climate Change Effects.

Determining the effects of changes in temperature and precipitation on coastal/marine systems

Changes to marine and estuarine water temperatures, salinities, and currents resulting from climate change are expected to dramatically affect the distribution, quantity, and quality of habitats and the LMRs that use them. Weather pattern changes resulting from climate change are also affecting watershed freshwater quantity and quality, not only in the streams and rivers themselves, but also in the estuarine and coastal habitats that exist downstream. These factors are greatly complicated by the wide range of human manipulations that have been imposed on watersheds and coasts, such as dredging, filling, impervious surfaces, and water diversion, all of which affect the quantity and delivery of freshwater. Better knowledge of the current state and rate of change in these interconnected systems will aid in management planning that considers changes in ecosystem structure, function, and integrity. In addition, despite significant improvements in global climate and earth system modeling, uncertainty still clouds our ability to precisely predict local changes in future temperature and precipitation patterns, and how species and their habitats will respond. Characterizing and reducing the uncertainty around these changes will aid planning and preparing for the future.

An example of the collaborative effort required is a project conducted by NOAA, the University of Washington, and Montana State University. Scientists on this project used climate and hydrologic models to predict changes in streamflow and temperature throughout the Columbia River basin into the 2080s (Figure 5). The results have been used to model changes in salmon habitat for the life stages that utilize freshwater. Efforts are currently underway to "down-scale" these models for use in local restoration efforts and recovery plans, and to determine changes in freshwater inputs into the downstream marine and estuarine systems.

Changes in freshwater inflow across the nation will dramatically impact the quantity and quality of stream, estuarine, and coastal habitats. As the impacts of climate change are occurring at broader scales, expanding studies to other regions and habitat types will be essential in our efforts to conserve critical habitats, understand the effects of temperature and drought on EFH and LMRs, and create policies that allow us to move forward in addressing the challenges of climate change.

Understanding and predicting effects of sea level rise and ocean acidification on the distributions and productivity of LMRs and their habitats

Continued and expanded assessments that synthesize disparate environmental and biological data are needed to advance our understanding of the current and future habitat impacts of changing climate. Such assessments are essential for the sustainability of marine and coastal habitats and the LMRs and coastal communities that depend upon them. Ocean acidification and sea level rise are two important consequences of rising levels of atmospheric carbon dioxide that are associated with climate change. Ocean acidification is expected to profoundly influence the form and function of coastal and open water habitats by altering the habitat suitability, especially for shellfish and crustaceans with shells and exoskeletons containing calcium carbonate. The effects of rising sea levels on coastal ecosystems can be equally profound. A more acidic ocean increases the solubility of calcium carbonate, weakening or even dissolving the shells of these organisms, especially of sensitive early life stages. The effects of rising sea levels on coastal ecosystems can be equally profound. Important coastal habitats, such as mangroves and marshes, which are highly productive nurseries and important storm surge buffers, may be unable to migrate inland fast enough to keep up with rising seas, especially when adjacent to developed coastal lands with established roads and buildings.

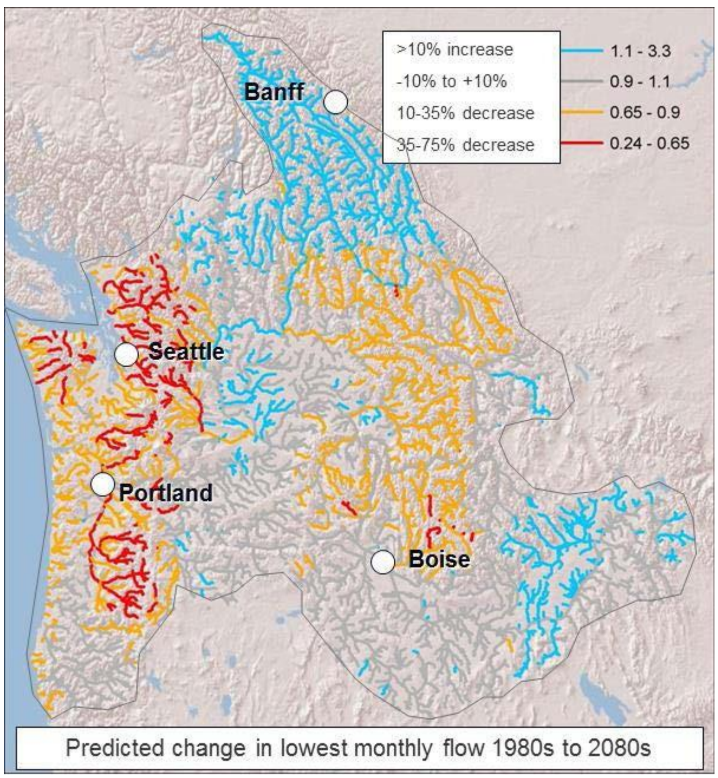

Figure 5. Predicted changes in stream flow in the Columbia River basin (1980s–2080s)

The NOAA Sentinel Site Program is an excellent example of an existing collaborative effort that leverages the Ecological Effects of Sea Level Rise Program. A range of scientific investigations are underway at Sentinel Sites with most efforts focused on sea level change and coastal inundation. This effort is about more than simply gathering data. It's about gathering people from many backgrounds and disciplines—NOAA and other federal experts, state and local government decision makers, university researchers, and other people who have a stake in a particular region. This place-based, issue-driven approach brings together NOAA and other federal, state, local, academic, and NGO partners addressing the impacts of sea level rise and coastal inundation in five geographies across the country. Cooperatives are designed to leverage one or more existing Sentinel Sites, including National Estuarine Research Reserves and/or National Marine Sanctuaries, and are intended to better coordinate and leverage planning, execution, and communication of results to all possible users. This ‘community of practice’ approach maximizes the efficiency and effectiveness of translating sound science to management action and stewardship.

Measuring and valuing carbon storage and sequestration

Blue carbon represents a vast, previously unrecognized natural carbon sink. Coastal salt marshes, mangroves, and seagrasses sequester carbon at rates 10 times higher than forested ecosystems and store carbon in their sediment that is often hundreds or thousands of years old. In addition to giving other important climate adaptation benefits to coastal communities like storm protection, nursery habitats for fish, and water purification, coastal blue carbon reserves are a crucial part of natural climate mitigation. However, there is a lack of guidance and procedures for estimating and valuing the storage and sequestration of carbon by coastal habitats, such as salt marshes, seagrasses, and mangroves. Thus it is difficult to determine how much carbon coastal habitats are sequestering and storing in a given area. In particular, there is a lack of data on how impacted coastal ecosystems lose carbon (e.g., how quickly a degraded salt marsh loses carbon and how quickly those services can be regained if we restore the salt marsh). Being able to estimate these values would help bolster the case that protection is less costly than restoration (both in dollar amounts and in the carbon that is not lost due to the destruction of these habitats) and to quantify how much carbon is sequestered and stored when degraded habitats are restored.

A good example of the potential carbon benefits from coastal restoration was recently completed by Restore America’s Estuaries (RAE) with support from NOAA. RAE assessed the carbon benefits of restoration in the Snohomish Estuary in Puget Sound, Washington, and determined that currently planned and in-construction restoration projects in the Snohomish Estuary will result in at least 2.55 million tons of CO_2 sequestered from the atmosphere over the next 100-years. This is equivalent to the 1-year emissions for 500,000 average passenger cars. If full restoration of all available locations were completed in the Snohomish Estuary, the sequestration potential jumps to 8.8 million tons of CO_2, equal to the 1-year emissions of about 1.7 million passenger cars.

Expanding these efforts to address our basic science needs can allow for improved ability to incorporate carbon services in programs and policies, as well as promote enhanced conservation of coastal habitats. This inclusion depends on improved scientific information on atmospheric carbon removal rates and emissions across different habitat types under different conditions. Simply having the information to understand, adapt to, and mitigate the effects of climate change is not sufficient to affect public policy. Internationally, the United Nations Intergovernmental Panel on Climate Change (IPCC) publishes comprehensive reports on the changing climate and how these changes are affecting a wide range of societal needs. Nationally, many public and private entities, including NOAA, are engaged in assessing climate change and communicating the information to a wide range of audiences. As development continues in the future, understanding blue carbon can help guide the development toward directions that preserve and enhance the carbon storage and sequestration by coastal habitats, which will not only protect and restore these habitats and the other ecosystem services they provide, but also contribute to efforts to reduce the impacts of increasing carbon dioxide concentrations on the global climate.

COUPLING HABITAT SCIENCE PRIORITIES TO ECOLOGICAL FORECASTS

The data and information products identified and developed from the HS&EF priority habitat science needs categories will be used to advance NOAA's habitat and species ecological forecasts. Ecological Forecasting was established as a field of study more than two decades ago and continues to gain traction as a means to integrate interdisciplinary capabilities into predictive tools for resource management and ecosystem applications (e.g., Clark et al., 2001; Valette-Silver and Scavia; 2003; Sandifer et al. 2012). While there are several definitions for ecological forecasting in the literature, NOAA defines ecological forecasting as follows:

Ecological forecasts predict likely changes in ecosystems and ecosystem components in response to environmental and human stressors (e.g., climate variability, extreme events and hazards, pollution, habitat change) and resulting impacts to people, economies and communities that depend on coastal ecosystem services. Ecological forecasts provide early warnings of the possible effects of ecosystem changes on coastal systems and on human health and well-being with sufficient lead time to allow corrective actions to be taken or mitigation strategies to be developed.

Based on this definition, NOAA has developed its Ecological Forecasting Roadmap (NOAA 2015b) to more effectively coordinate NOAA-wide ecological forecasting capabilities in executing a suite of historical, current, and planned forecasting actions to provide predictions in support of marine resource management (Stumpf et. al. 2012). NOAA has broad experiences in developing predictive ecological models. Over time, these activities could become operational ecological forecasts tailored to meet user-driven needs (Pittman et. al. 2007; Hare et. al. 2010). In an effort to focus and advance NOAA's ecological forecast efforts, the Roadmap initially addressed HABs, hypoxia, and pathogen forecasts. Building on the progress made in these areas, forecasting changes in the distribution of habitats and species was added to the Roadmap as of May 2014 and NOAA's Ecological Forecasting – Habitat and Species Distribution Technical Team was formed to define goals and activities for inclusion in the EF Roadmap. This team was subsumed into the HS&EF team to support both the NHCT and the EFR. The technical team will build upon NOAA's long history in ecological modeling to coordinate and promote development and application of new approaches to forecast, hind-cast, and now-cast major changes in the distribution of important coastal, marine, and Great Lakes habitats and associated species.

NOAA often strives to provide comprehensive spatial coverage using our ability to observe, geo-coordinate, and predict spatio-temporal distributions of coastal, pelagic, and benthic habitats. However, some facets of habitat and certainly selected species distribution remain more challenging to accurately and synoptically predict. Quantifying changes in habitat quantity and quality and defining species habitat affinities is often based on noisy and scattered sampling data. Thus, NOAA continues to invest in development and use of spatial-temporal predictive modeling techniques to forecast and map how changes in habitats modulate species distributions and ecosystem processes. The outputs of this research and geo-spatial assessment products are often used by managers and planners to make policy decisions and plans and to assess the outcome of human uses, climate change, and management actions (Costa et al. 2014; Menza et al. 2012, Rubec, et al. 1998).

Ecological forecasts of habitat and species distribution are inherently interdisciplinary, bringing together physical, biological, chemical, and socio-economic data sets depending on the science to address management needs. At each stage of their development, testing, and operation, ecological forecasts will require partnerships among and input from offices and labs across NOAA, at other agencies, and from within Academia and the private sector in order to assemble the multidisciplinary skills and data required. However, the first step for integration is initiate coordination with the key NOAA programs addressing habitat and species interactions, such as the NOAA Integrated Ecosystem Assessment and Biogeography Programs, the NOAA Habitat Conservation Team's Action Plan and Habitat Blueprint Focused Area Implementation Plans, NOAA Fisheries Climate Action Plan, and utilization of modeling and data management capabilities across NOAA line offices.

HS&EF FORECAST PLANS

The types of forecasts the HS&EF team plans to coordinate will span across various space and time scales and complexity in estuarine, coastal, and marine ecosystems (Fig 1). Spatially, the forecasts could range from addressing large marine ecosystems to a single habitat type within an estuary. However, in the near-term we will have a strong focus on coastal waters to develop products that are relevant to multiple natural resource management needs that have been defined by local, state, and federal institutions. The HS&EF team will primarily address scenario based predictive modeling over specified space, albeit with some activities providing temporal forecasts (e.g., predicting the timing and extent of coral bleaching). For example, a scenario-based forecast was developed through an integrated set of physical and biological models to predict the mortality of the Eastern oyster in Apalachicola Bay, FL, under various freshwater inflow management scenarios (Livingston et al. 2000; Monaco and Livingston, 1996). This ecological forecast has contributed to the allocation of the quantity of freshwater inflow by balancing ecosystem condition with human uses (e.g., drinking water) of the Bay. We anticipate replicating this type of ecological forecast to provide information that result in applied management actions in other locales and sets of conditions. Similarly, forecasts may vary in time including both long term forecasts of the impacts of climate change to seasonal forecasts of species' early life history stages.

NOAA's Coral Reef Watch Program provides a good example of a weekly to seasonal forecast. The Program's satellite data provide current reef environmental conditions to quickly identify areas at risk for tropical coral bleaching, where corals (a biogenic habitat) lose the symbiotic algae that give them their distinctive colors. The Coral Reef Watch Program uses computer software to evaluates the intensity of solar radiation, wind speed and sea surface temperatures (SSTs) when issuing tropical coral bleaching alerts.

Due to the complex suite of NOAA programs and projects addressing habitat science and ecological forecasting it requires the HS&EF team to narrow its coordination efforts and program activities ensure effective interactions and communications. Based on the NOAA habitat science priorities the HS&EF team will focus on three major activities: 1) determine how changes in benthic and emergent coastal habitats are related to and impact species' distribution, abundance, and production, 2) determine how changes in coastal and marine water temperatures and chemistry effect the same, and 3) evaluate forecasts across a continuum of data availability ranging from well-studied species to those that are relatively understudied, such as deep corals, and the reliability or certainty of ecological forecasts. These activities will serve as guidance on where and what we focus on over the next five years by evaluating data availability, habitat science needs, management requirements, and the ability to transfer lessons learned and results to other locales and regions.

There are numerous tools, bio-physical models, data sets, and computing requirements that can be applied to support the HS&EF primary activities. However, since the HS&EF effort is specifically focusing on predicting how changes in emergent, benthic, and pelagic habitats impact species' distribution, abundance and productivity we can define core components to support the HS&EF primary activities. These core components include mapping and modeling the current and future areal extent and condition of habitats. This work would consider the impact of a stressor (e.g., sedimentation) or cumulative impacts of multiple stressors, such as those associated with climate change on the future condition of emergent, benthic, and pelagic coastal habitats. A second major component of HS&EF studies is to define specie's habitat affinities for a single or a suite of habitats. This is key information needed for economically and ecological important species and critical to define for under-studied species as we attempt to move to ecosystem-based management. The first two components will be integrated by the use of existing and development of new species' habitat suitability models. Species' habitat suitability models can range from simple mathematical models (e.g., geometric mean) to complex ecosystem models (Ecopath/ Ecosim) depending on data availability, management needs, and geographic extent of study domain. Efforts will focus on defining and assessing the impacts of changes in key near-shore communities such as SAVs, corals or other biogenic reefs that provide structure and resources, and offshore pelagic habitats (e.g., changes in water temperatures). Thus, the HS&EF Technical Team will model changes in habitat due to natural or anthropogenic phenomena that will facilitate ecological forecasts resulting in a range in complexity of species' habitat suitability models.

Signature Actions

Below is a list of integrated signature actions from the NHCT and EFR that the HS&EF Technical Team is addressing in the near-term and the actions that will evolve over time based on NOAA habitat science and ecological forecasting needs and available fiscal and human resources. The bullets are consistent with the overall HS&EF priority areas described in this document and the sub-bullets represent ongoing work that the HS&EF team will continue to contribute both from a coordination stand point and also members of the HS&EF team are active participants in the projects.

- Address key science needs for priority habitats, including foundational habitat mapping, characterization and assessment, with emphasis on areas that will support multiple mandates and/or help advance ecosystem services valuation work.
    - Develop models to evaluate the resilience of coastal communities to changes in habitat which results in changes in the ecosystem services available to communities (NOS).
    - Advance NOAA's Coral Reef Watch to identify areas at risk for tropical coral bleaching (NESDIS).
- Conduct NHCT habitat & ecological forecasting efforts in NOAA Habitat Focus Areas where appropriate.
    - Provide ecological assessment and status of resources to provide baseline information to characterize the Choptank Complex HFA (NOS, NMFS).
    - Map benthic habitats based on existing data to support development of species habitat suitability models in Kachemak Bay HFA (NOS, NMFS).

- Examine how changing watershed patterns alter the flow of nutrients into the Biscayne Bay, and thus alter the habitat provided for fish, protected species, and other organisms in the Biscayne Bay HFA (NMFS, OAR, NOS).
- Examine how changing water usage in the Biscayne Bay watershed affects the mesohaline habitat used by many juvenile species in the bay HFA (NMFS, OAR).
- Conduct investigations to forecast how changes in pelagic and benthic habitats impact species distributions.
    - Forecast how changes in estuarine water temperature and salinities impact the distribution of early life history stages of key NOAA managed fishery species in the mid-Atlantic region (NOS, OAR,NMFS).
    - Forecast how long-term climate change impacts kelp forest distribution and species associated with the kelp canopy in Southern California (NOS, OAR, NMFS).

Development and testing of multi-disciplinary ecological forecasting models often occurs across organizational boundaries via working partnerships among scientists. While offices and labs within NOS, NMFS, OAR, NESDIS, and NWS will likely lead many ecological forecasting efforts addressing how habitat modifications impact species distributions, they will do so in partnership with scientists from across NOAA, with other State and Federal agencies, and with academia and private sector. Similarly, turning the results of model development into an ecological forecast products and delivering those products to the appropriate users are specialized activities requiring experience and understanding of the needs of users. While some of that experience can be found within NOAA research centers or labs, it will be necessary to engage partners, such as state and local managers, to ensure that products and data can be accessed and used by natural resource managers. Ultimately, plans are for the HS&EF team to aid in transitioning habitat science research to applications that directly support marine resource management actions.

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Online Resources:

http://oceanservice.noaa.gov/ecoforecasting/

http://coastalscience.noaa.gov

http://www.habitat.noaa.gov/pdf/NAO_216-

117_UNSEC_Signed.pdf

http://www.nmfs.noaa.gov/sfa/laws_policies/national_standards/index.html

http://www.naturalcapitalproject.org/InVEST.html

http://www.climate.gov

http://www.noaa.gov/climate.html

Appendix I. NOAA Habitat Science and Ecological Forecasting Technical Team Members

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Appendix II. "Cross walk" needs/activities for NHCT Habitat Science Sub-group priorities with those identified by the EFR's Habitat and Species Distribution Team.

Science Needs/Priorities Document	Ecoforecast Goals	Ecoforecast Products
I. Foundational Habitat Mapping, Characterization, and Assessment a. Mapping ecosystems and landscapes b. Assessing the extent, condition, status, and trends of key habitat types c. Improving remote sensing technologies for habitat mapping d. Improving the accessibility of synthesized habitat data for making management decisions	Goal 1 Determine how changes in benthic and emergent coastal habitats are related to and impact species' distribution, abundance and production.	Define ecological "hotspots" for protected and managed species and forecast changes in their distribution and abundance over time based on changes to habitats and management actions.
II. Linking Habitats and LMR Productivity a. Understanding habitat use by different LMRs and life stages b. Understanding the relationship between habitat linkages and LMR productivity c. Providing habitat information to support stock assessments d. Determining the efficacy of habitat conservation and restoration methods	Goal 1 Determine how changes in benthic and emergent coastal habitats are related to and impact species' distribution, abundance and production. Goal 3 Evaluate across a continuum of data availability ranging from well-studied species to those that are relatively understudied, such as deep corals, and the reliability or certainty of forecasts.	Use results of EF-HSD forecasts to define and evaluate survey designs that support adaptive sampling approaches to monitor and assess habitat quantity and quality and the distribution and abundance of associated species. Identify priority habitat restoration areas based on higher probability of success with respect to their ability to recover and/or the resiliency of restored habitats.
III. Value of Nature a. Identification and valuation of ecosystem services b. Advancing the understanding and use of ecosystem services in habitat restoration planning and prioritization		Forecast loss or gains in ecosystem services provided by habitats and animals from anthropogenic and natural stressors on coastal ecosystems.

IV. Climate Change Effects a. Determining the effects of changes in temperature and precipitation on coastal/ marine systems b. Understanding and predicting effects of sea level rise and ocean acidification on the distributions and productivity of LMRs and their habitats c. Measuring and valuing carbon storage and sequestration	Goal 2 Determine how changes in coastal and marine water temperatures affect 1 above.	Evaluate the resiliency of habitats to coastal storms and stressors. Forecast and understand species' responses to climate changes including increased water temperature, changes in precipitation effecting flow, ocean acidification, and biogeochemical cycles.

Appendix III. Descriptions of NOAA's high-priority habitat science needs identified by NHCT science sub-team members.

Table 1. List of Foundational Habitat Mapping, Characterization, and Assessment Science Needs.

Science Need	Description
Identification of benthic habitats, particularly critical and sensitive habitat types.	Ship-based multibeam surveys; LIDAR in very shallow water environments. Bathymetric maps provide the broadest context for the shape and structure on the seafloor, which are critically important to understanding habitats that might be present. More robust predictive models of biological utilization are also in development to aid the habitat identification process.
Determine biodiversity associated with identified habitats (particularly sensitive/critical habitats like deep coral communities), their biogeographies, and connectivity among habitats that support all life stages of fishery and protected species.	Though physical habitat types can be verified quickly via ground-truthing, additional time is required to identify the associated sessile and mobile macrofauna. Visual surveys alone are not sufficient for identification of many species, so samples must be collected and analyzed. Establishing connectivity among habitats requires significantly more work and is often not easily accomplished. Using the right tool for the job requires identifying the specific questions to be answered. AUVs and ROVs are often used below SCUBA depth for visual surveys, sample collection, and mapping (e.g., physical and chemical water column properties).
Coastal habitat mapping, characterization.	Better information describing estuarine and coastal nursery and prey habitats and their contributions to offshore living marine resources productivity is needed for better stock assessment and living marine resources management. This information is needed over a range of scales.
Coastal watershed habitats.	Information on effects of loss of freshwater wetlands in coastal watersheds, due to urbanization and/or silviculture, on receiving estuaries and coastal waters, and direct and indirect effects on marine species.
Continued development of mapping remote sensing technologies for coastal habitat and out to the shelf break.	Investments needed to expand the accuracy and quality of remotely mapped habitats (e.g., multispectral sensors) to enable an accurate accounting of the extent and changes over time of both pelagic and benthic habitats.
Water column characterization.	Acoustic remote sensing allows exploration of the marine environment between the ocean surface and the seafloor. The water column signature often provides important clues about benthic habitats that cannot be gathered from bathymetric data. Many multibeam sonar systems can concurrently collect bathymetric and water column data. Additional tools (e.g., CTDs, wave gliders, AUVs) would be needed to conduct full physical and chemical characterizations of priority areas.

Table 2. List of Habitat Usage – LMR Productivity science needs.

Science Need	Description
Characterization, mapping, monitoring, and assessment of water column habitats and their species affinities.	Variation in water characteristics affects habitats of both sedentary and migratory species. These factors change with currents, weather, climate, etc., so a standardized approach is needed to characterize and monitor water column variability and its impacts on LMR stocks. Shifts in the spatial range of individual species are often episodic responses to extreme conditions (which must be established and characterized), rather than monotonic responses to changes in the mean conditions.
Development of methods to integrate habitat information into stock assessments (both fish and protected species).	The highest level of stock assessment quality includes integrating ecological factors into stock assessments, including habitat, oceanography, food chains. Currently, stock assessments generally assume that habitat (and other ecological) changes are reflected in population dynamics, but the actual mechanisms are often unknown. Incorporating habitat (and other factors) into the assessments could improve accuracy and precision. An improved understanding of the relationship between habitat characteristics and population dynamics is a prerequisite for practical definitions of the essential fish habitats.
Development of user-friendly access to habitat data for use in management decision making.	To get the maximum return on habitat research, it is critical that managers have ready access to the scientific information they need to make informed decisions. This includes geospatial databases, maps, as well as ecological information, such as habitat affinities for LMR stocks.
Development of compensatory mitigation valuation and restoration models.	To make informed decisions, habitat managers need models to assess mitigation and restoration options for the specific LMRs in their regions. This is especially important for addressing an unavoidable loss situation.
Research on importance of various habitats during multiple life history stages.	The single biggest improvement that we could make to EFH and HAPC (habitat areas of particular concern) designations would be the ability to predict impacts to growth and reproduction as a result of changes to various habitats. Our current designations are meaningless because they do not make the distinction between habitat that is critical to growth/ reproduction and habitat that is used simply as a medium of passage.
Translating/quantifying the benefits of specific habitats to stock productivity.	To better understand stocks' dependence on particular habitats, improved research and modeling is needed to estimate the relationship between suitable habitat availability and stock productivity.
Understanding the efficacy of Marine Protected Areas (MPAs) in protecting ecosystem function.	Plenty of studies have evaluated the efficacy of MPAs in increasing the abundance, size, and productivity of exploited stocks, but far fewer have looked at other indicators of ecosystem function.

Research and development for habitat restoration methods, and long-term monitoring to assess efficacy.	Restoration projects should be designed as experiments with long-term, comprehensive monitoring. Success in restoring ecological function can most credibly be determined using comprehensive, long-term monitoring (i.e., decades), which is much longer than monitoring is usually supported. It’s expensive, but important.
Development of a metric to capture the resource benefit of EFH.	The appropriate determination tool should be developed and management species data sets evaluated to determine where this can be done and filling data gaps where needed should be prioritized. The benefit of EFH linked to habitat value should be better characterized, the ecosystem context of habitat benefits shown, and area of larval distribution linked to adult biomass, etc.
Better understanding of anthropogenic stressor thresholds.	Habitat management should prioritize projects and evaluate potential success; better understanding of the amount of restoration needed to restore ecosystem function is needed to prioritize implementation.
Understanding how restoration projects are able to demonstrate effectiveness and not create unintended harm.	Most restoration projects are not designed to quantitatively measure the biological improvements to the habitat of concern. We need to have baseline measures and ongoing monitoring both in the restoration areas and the adjacent areas to be able to assess the success/failure of habitat restoration efforts and know whether our interventions are not only successful biologically, but also worth the economic cost.

Table 3. List of Value of Nature Science Needs.

Science Need	Description
Ecosystem services identification and valuation.	More work is needed to understand the role of habitat in trophic and community interactions, and is particularly important for understanding the economic value that habitat contributes to supporting LMR's, commercial, recreational, and protected. It is also critical to understand the specific benefits habitat provides for human communities (i.e., storm protection and water quality improvements) and also the impacts of healthy habitats on human health and well-being (impacts of a diversity of habitats on human relaxation/enjoyment and health, including physiological measures of health such as lower blood pressures.). This would also include a better understanding of how a diversity of healthy ecosystems impacts the functioning of the human body (e.g., autoimmune development or immune responses, etc.).
Guidance and procedures for estimating and valuing coastal blue carbon.	There is a lack of guidance and procedures for estimating and valuing coastal carbon, which makes it difficult to determine how much carbon these coastal habitats (salt marshes, mangroves, and seagrasses) are sequestering and storing in a given area. These values would be helpful to bolster the case that protection is less costly than restoration (both in dollar amounts and in the carbon that is not lost due to the destruction of these habitats) and to quantify how much carbon is sequestered and stored in these habitats after restoration takes place.
Capacity and expertise to quantify impacts of habitat protection and restoration projects on carbon storage.	There is a need to show the value of habitat protection and restoration projects in terms of how much these habitats store and sequester carbon, both before and after restoration.
Greater understanding of ecological and economic values of green infrastructure/living shorelines.	A better understanding of which green infrastructure/living shoreline design scenarios work best for different management objectives (EFH, protection from storms, etc.) and different habitat types, as well as an understanding of the economic values of these designs to support ROI (return on investment) questions.
A better understanding of the habitat trade-offs associated with green infrastructure (living shoreline designs).	There is a need to show the habitat trade-offs associated with living shoreline designs to provide science that will support EFH decisions. Living shoreline designs vary greatly, so more science to support one design over another in a specific habitat or to support a living shoreline of a specific width is needed. Specific information that would be valuable includes: the ecological trade-off between intertidal and subtidal habitats, comparisons of rock and mud, and the amount (acres) needed for fish species with defined EFH.

Understanding cumulative impacts to coastal ecosystem services from hardened shorelines, such as bulkheads and riprap.	Studies have shown that there are negative impacts of hardened structures on coastal habitats, but long-term studies to show the cumulative impacts from bulkheads and riprap as applied though the Nation Wide Permit (NWP) for shoreline stabilization would be valuable.
Understanding the long-term efficacy of various shoreline stabilization designs for physical performance, ecological resources, and water quality.	Long term data for comparisons of various shoreline stabilization techniques will be helpful for further guidance encouraging the use of living shorelines as a shoreline stabilization technique.
Advancing the use of ecosystem services in habitat restoration planning/prioritization, using Habitat Blueprint Focus Areas as pilots.	Pursue short-term pilots that deliver immediate benefits, such as modeling of economic impacts of different release schedules by U.S. Army Corps of Engineers in Russian River to different recipients of ecosystem services. In addition, pursue longer term efforts that advance the use of spatially explicit models of ecosystem service flows, allowing NOAA to more strategically develop restoration plans by better understanding the impacts of alternative management options to the full spectrum of services.
Research on how infrastructure can be designed that supports both societal needs (for physical protection from storms) and ecological functions that sustains the productivity of LMR stocks.	Infrastructure should be designed as an experiment, encompassing both the efficacy in providing physical protection and ecological functioning.