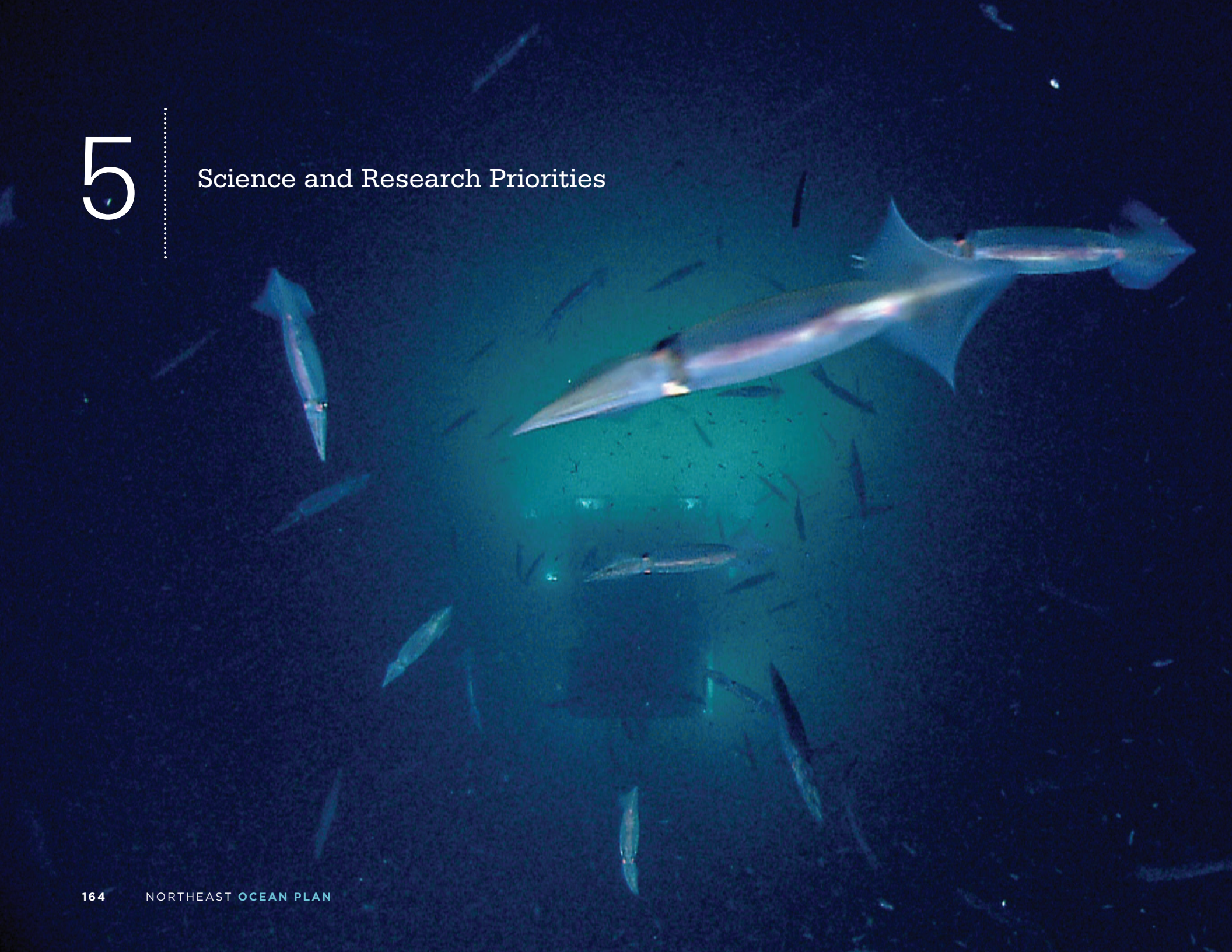# 5 | Science and Research Priorities

Throughout the development of this Northeast Ocean Plan (Plan), the Regional Planning Body (RPB) dialogue and public input emphasized the need for agency decisions to be based on sound data and science. In addition to the production of peer-reviewed maps and data characterizing the ocean resources and activities in Chapter 3, outreach and engagement throughout the planning process led to an increased understanding of the information gaps that could be priorities for new science and data development. This outreach and engagement also resulted in the identification of several overarching issues that need new research.

These issues include understanding the implications of changing ocean conditions, the interactions between human activities and the effects of human activities on the ocean environment, and the desire to continue advancing a broader ecosystem perspective and approach to ocean management. Basic research underpinning these issues was a common thread of many conversations, as people pointed out the need for marine life surveys, enhanced understanding of potential cultural resources in the marine environment, and a greater understanding of the footprint and impact of existing human uses.

Collectively, these discussions provided great insight for the development of the Plan, and just as importantly, helped lead to the RPB's recognition that the Plan, as well as management of ocean resources and activities in general, should be an adaptive effort continually informed by new data and science. These discussions also resulted in a long list of data and information gaps, science and research priorities, and ideas about how to address and organize these priorities. Some of the data and information

gaps identified were actually addressed by the maps and data described in the Plan and incorporated into the Northeast Ocean Data Portal (Portal). Other short-term priorities with specific responsible parties are described in the actions to maintain and update data on the Portal, included in Chapter 3 and also summarized in Chapter 4. The remaining science and research priorities are included in this chapter and organized as opportunities for the various governmental and nongovernmental organizations in the region to advance the scientific underpinning of a more comprehensive, ecosystem-based approach to ocean management.

This chapter begins with a description of the **RPB's role in advancing science and research priorities**. It then provides a high-level **summary of the science and research priorities** and ends with a section devoted to providing a **detailed description of each of the six science and research priorities**, drawing from the individual data and information gaps and potential topics that were identified throughout the planning process.

RPB ROLE IN ADVANCING SCIENCE AND RESEARCH PRIORITIES

As described in Chapter 4, the RPB's intent is to have a convening and coordinating role for achieving the science and research priorities identified in this Plan. This approach recognizes that there are many existing federal and state agency initiatives, academic and research institutions, regional science consortia, and other nongovernmental organizations already advancing progress through existing science and research plans; the RPB can help make connections between these existing efforts and leverage and coordinate activities. There is also recognition that this chapter outlines an ambitious agenda that will be refined and accomplished through existing programs and partnerships, and that the RPB and its regional partners will need to be opportunistic when leveraging or funding opportunities arise.

Therefore, the RPB will periodically convene regional partners and scientists to review this list of priorities, discuss progress, refine these priorities, and identify potential partnerships to achieve these priorities. These activities will occur through the RPB's periodic public meetings, the Ecosystem-Based Management (EBM) Work Group, the Northeast Regional Ocean Council (NROC), and potential workshops focusing on particular topics. As mentioned in Chapters 3 and 4, RPB entities will collaborate to develop an integrated regional ocean science and research agenda, including identifying opportunities, as appropriate, for coordination and collaboration with the White House's Subcommittee on Ocean Science and Technology (SOST) on the overall agenda, and working with the the National Oceanographic Partnership Program (NOPP) to facilitate discussion and support of specific research projects.

SUMMARY OF SCIENCE AND RESEARCH PRIORITIES

The RPB developed the following six priorities to organize potential data, information, and research activities into a framework for advancing scientific knowledge and data in support of ocean management decisions. The priorities are organized with the understanding that the first three are foundational in many ways to the last three. This framework is generally aligned with the science required to advance ecosystem-based management, as it has been defined to date. Individual elements within each of the six overarching priorities (especially for the first three) correlate with many of the ocean resources and activities described in Chapter 3.

THE SIX PRIORITIES:

1. Improve understanding of marine life and habitats

Furthering our understanding of the distribution and abundance of living and nonliving elements of the marine ecosystem is critical for ocean management. Analyses and syntheses to support the Plan provide an unprecedented amount of regional marine life and habitat data, but important data gaps remain, including in basic survey coverage and species' movement data. As the type of information collected during surveys informs many other aspects of ocean management, filling geographic and temporal gaps in survey coverage is a priority.

2. Improve understanding of tribal cultural resources

Work to identify and characterize cultural resources and submerged paleocultural landscapes in the Northeast ocean is ongoing. The results of these efforts will improve our understanding of past human activities in offshore areas and their contribution to the Northeast's cultural heritage.

3. Improve understanding of human activities, coastal communities, socioeconomics, and interactions between uses

Improving the characterization of past, present, and future human activities is critical for understanding the compatibility and interactions between uses. There are gaps in existing information for some human activities (certain fisheries, recreational activities, and archaeological and cultural resources in the marine environment, for example). Additionally, the spatial patterns and the intensity of human activities change through time. All of these changes will have corresponding effects on coastal communities, local and regional economies, and culture. Additionally, it is often difficult to assess the importance of ocean resources and uses beyond traditional economic assessments (i.e., quantifying the number of jobs, earned income, or GDP), which can omit important nonmarket values that are important to coastal residents and communities.

4. Characterize the vulnerability of marine resources to specific stressors

Identifying which marine resources (species and habitats) are particularly vulnerable to specific stressors such as water column infrastructure, benthic disturbance, and ocean noise, as well as quantifying the impacts of stressors and resource vulnerability, is a priority research need.

5. Characterize changing environmental conditions, particularly resulting from climate change, and characterize resulting impacts to existing resources and uses

Understanding how climate change and other mechanisms that lead to shifting environmental conditions affect marine resources and human uses is critical for their management and for future ocean planning. More work is needed to document and monitor changes to ocean resources (e.g., ocean chemistry changes such as ocean acidification and shifts in marine life distribution and abundance) and resulting changes in human activities (e.g., commercial fishing and recreation) to determine potential ecosystem and human impacts. Such information could potentially be used to support forecasting models to help assess if the available science-based information adequately and accurately characterizes conditions over the full duration that management decisions would be in effect.

6. Advance ecosystem-based management by building on the previous priorities and also including cumulative impacts and ecosystem services

Continuing to promote an ecosystem-based approach to ocean planning and management requires advances in the five previous priorities, as described. Additionally, moving toward ecosystem-based management involves continuing the identification and quantification of ecosystem services;[1] the characterization of ecosystem function, resilience, and recovery; and advancing methods for assessing cumulative impacts. Finally, there is a need to review the existing legal framework of federal laws related to ocean management and identify opportunities to incorporate science and research results to help continue to move toward an ecosystem-based management approach.

The following section describes elements of the six priorities that emerged through the development of the Plan. As part of Plan implementation, the RPB will routinely convene partners to discuss these six priorities, noting progress and opportunities to address them.

SCIENCE AND RESEARCH PRIORITY:
Improve understanding of marine life and habitats

Further exploring the relationships between marine life and habitat could highlight important ecological processes, improve the predictive capability of the MDAT and other marine life models, and inform management issues.

Many discussions during the planning process pointed to the need for foundational information to improve our understanding of marine life and habitats so as to increase the effectiveness of ocean management. Basic survey work to understand the presence and abundance of marine life and habitats is one such fundamental scientific research need. The many survey efforts underway or completed in the region over recent decades provide a wealth of information, and the marine life products available on the Portal, and described in Chapter 3, draw from their results. However, survey efforts are not distributed uniformly across the region, resulting in undersampling of some areas. As a result, the distribution and abundance of certain species is not well documented. Additionally, certain species' life histories or behaviors are not well understood. Basic information resulting from survey work can address these issues and is necessary for management needs.

One such use of this essential information that has been a focus of much recent discussion is the continuation of habitat classification efforts. Each of the Northeast states, the New England Fishery Management Council (NEFMC), several academic institutions, and several federal agencies collect and/or interpret habitat data for various purposes. Through national standards, such as the Coastal and Marine Ecological Classification Standard (CMECS),[2] there are tools

in place to provide a framework for enhanced understanding of habitat, habitat distribution and variability, and other considerations.

An additional use of information on individual species is to enable examination of the spatio-temporal overlap of species and species groups, which could inform analyses of interspecies interactions. Such thinking extends to considerations of the linkage between species and habitats, since the concept that ocean habitats drive patterns in marine life is implicit in the Marine-life Data and Analysis Team (MDAT) modeling framework for marine mammals and birds. Further exploring the relationships between marine life and habitat could highlight important ecological processes, improve the predictive capability of the MDAT and other marine life models, or inform other management issues.

Many of these considerations (e.g., the need for basic understanding of species, habitats, and their interactions) underlie the concepts, or are included directly, in elements of the draft Important Ecological Area (IEA) Framework. The RPB (as informed by the EBM Work Group and public discussion) identified a number of marine life and habitat datasets that would improve characterization of IEA components by filling information gaps for marine life and habitats not fully characterized in Portal data. Existing datasets could also be reanalyzed or

reinterpreted to better characterize IEA components. Data and research needs to support components of the IEA Framework include improvements to the characterization of ecosystem structure, function, and connectivity.

Given these considerations, the RPB has identified the following important research topics, recognizing that they are related in many ways:

MARINE LIFE AND HABITAT SURVEYS
New surveys will help fill gaps in current understanding of the distribution and abundance of marine mammals, birds, fish, sea turtles, bats, corals, kelp forests, and other habitats. Existing data can help inform priorities for future surveys by identifying current gaps in survey coverage (e.g., in coastal and estuarine environments). Several projects collecting marine life movement data provide the opportunity to develop methods to analyze, display, and communicate

this new information spatially. There is also an opportunity to coordinate with the many entities that will be conducting future surveys and analyses to support and complement the types of data products provided on the Portal (i.e., by providing MDAT methodology for researchers' use in designing surveys). The results of this work would provide more robust spatial products depicting marine life and species distributions and movement patterns for use in ocean management decisions.

HABITAT CLASSIFICATION AND OCEAN MAPPING
Continuing and expanding upon the work of the Northeast Regional Ocean Council (NROC) Habitat Classification and Ocean Mapping Subcommittee, specific areas of interest include developing better spatial and temporal representations of pelagic habitats (e.g., upwelling areas or fronts) and compiling seafloor mapping products (e.g., bathymetry, backscatter intensity) for analysis/interpretation with regional geological datasets (e.g., sediment) to aid in the development of descriptions of seafloor habitat. There is an opportunity to continue to coordinate these efforts through the US Federal Mapping Coordination website[3] and through the National Oceanic and Atmospheric Administration (NOAA) Integrated Ocean and Coastal Mapping Program. Applying the CMECS and translating existing regional habitat data into

CMECS would result in more comparable maps of benthic and pelagic habitats. These maps, plus improved depictions of pelagic habitats, would provide essential context for many other studies and analyses by providing, for example, a physical habitat framework for managing ocean resources, and for informing research related to assessing environmental changes.

SPECIES AND HABITAT RELATIONSHIPS
Understanding the relationships among marine life taxa and between habitat and marine life would address information needs related to topics such as predation, symbiotic relationships between species, and the influences of habitat and habitat parameters on species' distribution and abundance. Examining marine life products on the Portal is a first step toward these types of analyses. A workshop among wildlife and habitat experts would also advance understanding of how to use habitat and species maps and models together. The results of this work would be an enhanced understanding of the relationships among species, which could address many management-related questions; and an enhanced understanding of relationships between species and habitats, which could help improve the predictive power of marine life models, among other benefits.

SCIENCE AND DATA TO ADVANCE THE IDENTIFICATION OF IMPORTANT ECOLOGICAL AREAS

Developing new products that build on the marine life and habitat data in the Portal may help improve the characterization of IEA components related to ecosystem structure, function, connectivity, and dynamics. The results of the following individual tasks will improve the understanding of ecological relevance of IEA components, help advance the IEA Framework, and provide useful stand-alone products for decision-making.

Ecosystem structure:

• Develop metrics of persistence of abundance for marine life, including benthic fauna and other habitat-forming species.

• Understand species and habitats for which cold spots (e.g., areas of low abundance, low richness, or low diversity) are relevant and important.

• Determine and review thresholds for cold spots of productivity, biodiversity, and marine life abundance.

• Develop a multi-taxa index of biodiversity.

• Develop core abundance areas for species with low fecundity, slow growth, and longevity.

• Develop core abundance areas for species groups sensitive to impacts including warming waters and acidification.

• Develop core abundance areas for mammals, birds, and fish (monthly or seasonal averages).

• Identify and map seal haul out areas.

• Identify and map the distribution of ecologically rare species and habitats.

• Map the distribution and abundance of benthic fauna, including crustaceans.

• Map the distribution/abundance of kelp forests and other macroalgae.

• Map the distribution of bivalve-dominated communities.

• Map the distribution of sea grasses and other tidal vegetation.
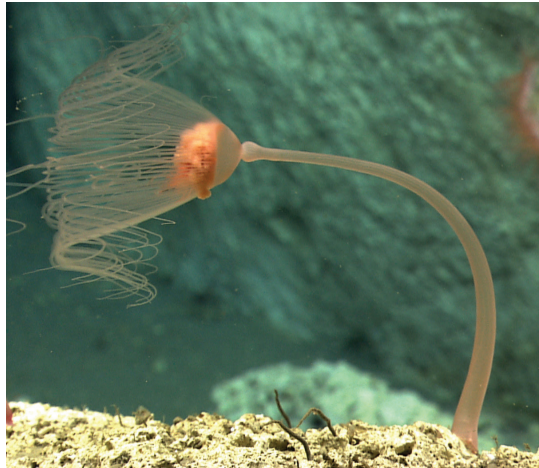
Ecosystem function:

• Develop multi-taxa metrics of primary and secondary productivity.

• Develop metrics of food availability.

• Identify and map the distribution of keystone species, foundational species, and ecosystem engineers.

• Map rolling closures and spawning protection areas for fish.

Ecosystem connectivity:

• Characterize pelagic processes that facilitate multiple ecosystem functions.

• Integrate marine life movement and migration information from tracking and telemetry data (including nighttime information where data is available).

Ecosystem dynamics:

• Specify times of importance for particularly dynamic ecosystem elements that support IEAs.

• Document changes in phenology due to climate changes.

• Address the concept of persistence as it relates to IEAs (in time and space) by using available time series of data to identify areas and times of year with historically persistent high productivity, abundance, and richness, for example.

SCIENCE AND RESEARCH PRIORITY:
Improve understanding of tribal cultural resources

Ocean management decisions require the identification of existing and potential tribal cultural resources. A project funded by the Bureau of Ocean Energy Management (BOEM) and the Rhode Island Coastal Resources Management Council, *Developing Protocols for Reconstructing Submerged Paleocultural Landscapes and Identifying Ancient Native American Archaeological Sites in Submerged Environments*, is scheduled to be completed in 2016. This project will collect new spatial data that expands existing knowledge of submerged Native American archaeological sites in the Northeast. In addition, the project will generate a Paleocultural Landscape Model that identifies seafloor environments with varying archaeological sensitivity for containing ancient Native American archaeological resources; the model's results will likely be representative of the variability to be encountered in the southern New England offshore environment.

Additionally, tribal resource uses are fundamentally connected to natural resource footprints. Plan data and information provide the opportunity to better understand these relationships. The marine life and habitat data developed for the Plan can provide context for current and historical tribal resource use for sustenance. Ecological data and information can be used to identify the habitat characteristics, distribution, and abundance of marine life in areas of significance to tribes.

The RPB has identified the following topics to advance the understanding of tribal cultural resources:

SUBMERGED ARCHAEOLOGICAL AND PALEOCULTURAL LANDSCAPES

Potential future work identifying submerged archaeological and paleocultural landscapes partially depends on the results of the BOEM study. Nonconfidential data or maps resulting from the project can be incorporated into the Portal. In addition, any lessons learned or methods can be applied in other parts of the region. Lastly, researchers may be interested in further exploring and characterizing areas of potential archaeological sensitivity, as identified by the Paleocultural Landscape Model. This work will result in an improved understanding of submerged landscapes of importance to regional tribes, and improved techniques for identifying them, which will support the regulatory process.

IDENTIFICATION OF AREAS OF CULTURAL SIGNIFICANCE USING MARINE LIFE AND HABITAT DATA

As described in the Cultural Resources section of Chapter 3, tribes intend to use marine life and habitat data on the Portal to demonstrate areas of cultural relevance during regulatory consultations. This use of existing data also presents an area of potential research and development. Maps of culturally important resources, such as shellfish habitat or diadromous fish species, should be assessed for their potential to demonstrate areas of cultural significance. Results could include the identification of areas of importance for current or historical sustenance and areas that may be a priority for habitat restoration. The results could also support tribes in promoting an ecosystem-based approach to identifying and determining impacts to potential cultural resources.

SCIENCE AND RESEARCH PRIORITY:

Improve understanding of human activities, coastal communities, socioeconomics, and interactions between uses

As new data are collected for existing and emerging human uses, there will continue to be opportunities to examine real and potential interactions through simple spatiotemporal overlays and more complex analyses.

The need to better understand human activities and coastal communities' reliance on and linkage to the ocean and its resources was a recurring topic during the development of the Plan. A better understanding of the socioeconomic factors and characteristics of human activities was also emphasized, as was the need to understand potential and real interactions between and among human uses.

Basic work to improve the characterization of human activities is a fundamental research need. Data available on the Portal and described in Chapter 3 related to shipping, fishing, recreation, aquaculture, energy and infrastructure, and sand resources, represent the results of extensive engagement with industry, public, and agency experts on these topics. Discussions with these experts also identified several areas where more work is needed to fill gaps in our understanding of human activities in the marine environment (e.g., as described later in the first element under this priority).

Planning discussions also highlighted the need to acknowledge and characterize "nonmarket" attributes of human activities, marine life, and habitats. In addition to economic "market" values, marine resources and activities generate nonmarket values that affect human well-being, but are not directly measurable in traditional economic assessments (for example, the value beachgoers derive from walking along a clean beach). Presently there are gaps in our knowledge of basic nonmarket values, how to measure or otherwise account for them, the implications for management of ocean uses and resources, and the connections to coastal communities. Further research could help improve understanding on this topic.

Enhanced characterizations of human activities, along with improved understanding of nonmarket values of human activities and the natural environment, would result in a better understanding of potential interactions between and among human uses, including the potential impacts of new uses. As new data are collected for existing and emerging human uses, there will continue to be opportunities to examine real and potential interactions through simple spatiotemporal overlays and more complex analyses. In particular, monitoring data associated with actual project construction and operation will provide ample information to assess real and potential conflicts for projects as they are sited.

The RPB has identified the following inter-dependent topics that will contribute to an increased understanding of human uses, coastal communities, socioeconomics, and interactions between uses of the offshore environment:

MAPS AND CHARACTERIZATIONS OF HUMAN ACTIVITIES

The following specific priorities were identified to better understand existing human activities and the connections between coastal communities and the ocean. The result of this work would provide information about human activities, which are not well documented on a regional basis.

- Better assess existing and potential changes in vessel traffic patterns through additional interpretations of Automatic Identification System (AIS) data, including maps showing the relative density of unique vessel transits, monthly or seasonal patterns for different vessel types or cargoes, and potential future traffic changes resulting from market conditions, Panama Canal expansion, or other factors.

- Improve the characterization of commercial and recreational fishing activity in the region, including fisheries that are not in the Vessel Monitoring System (including recreational fisheries, lobster, and fisheries targeting pelagic species, for example) and locally important fisheries, and improve our knowledge of the effects of changing fish species' distribution and abundance on the spatial footprints of commercial fisheries. Explore the ability of AIS data to address some of these gaps.

- Continue to fill gaps in the knowledge of cultural and historic resources in the offshore environment.

- Continue to develop spatial and temporal characterizations of regional recreational activity, including studies of relationships between coastal communities, and of the local economic benefits of recreational activities.

- Develop a regional inventory of potential offshore sand resources out to eight miles, and of onshore locations in coastal communities potentially requiring sand resources, leveraging existing and future state efforts.

- Correlate areas of the ocean used by particular human uses and particular coastal communities (e.g., by depicting the home ports related to particular fishing grounds or developing maps of offshore navigational place names and their relevance to coastal communities).

NONMARKET VALUATIONS OF OCEAN RESOURCES AND USES

More study of the social and intrinsic values of ocean resources and activities to local communities would enhance our ability to incorporate nonmarket values into specific ocean management decisions. Such research should include developing and testing methods for assessing nonmarket values and developing tools that incorporate these values in an assessment of the costs and benefits of various decisions. The result of such research would be an enhanced ability to assess and incorporate nonmarket values into specific ocean management decisions.

INTERACTIONS BETWEEN HUMAN ACTIVITIES

New research to increase understanding of the interactions between human uses should assess the potential for conflicts between existing and potential new human activities (e.g., activities that can no longer occur in a particular area, activities that become limited in a particular area, or activities that can only occur in a particular time frame). This element requires setting a baseline condition of human uses, for which Plan data may be useful, depending on the specific issues being examined. In addition, data and information developed under this topic may be used to assess opportunities for positive or reinforcing interactions between human uses, such as colocating different activities (e.g., offshore wind and aquaculture). This work would result in additional information for use in assessing potential impacts to human uses from possible siting of new uses.

④

Characterize the vulnerability of marine resources to specific stressors

Stakeholders, RPB members, and scientists identified the need to better understand the vulnerability of marine resources to specific stressors as an important priority for advancing comprehensive ocean management. As a result, the Marine Life & Habitat section in Chapter 3 references initial maps of marine life species grouped by their sensitivity to a few specific stressors, based on available research. However, available research quantifying relationships between marine resources and specific stressors is limited. Therefore, new research is necessary to characterize the potential vulnerability of marine resources to human activities, especially those activities that are emerging or evolving in the region, such as offshore renewable energy, aquaculture, and the extraction of offshore sand for coastal replenishment.

The RPB has identified the following general science and research topics related to understanding the vulnerability of marine resources to specific stressors:

MARINE LIFE VULNERABILITY TO SPECIFIC STRESSORS

New research to study the effects of various disturbances on marine life will help characterize species' vulnerability to particular stressors. Research could provide vulnerability characterizations within broad categories of disturbances such as benthic disturbance, water column infrastructure, and sound, with the intent to develop more specific disturbance-vulnerability groupings longer term, as additional studies (and project-specific monitoring requirements) are completed (e.g., birds and offshore wind energy, sources of sound and resulting effects on marine species, and fish and submarine cables). Baseline monitoring of species would be necessary in many cases; for example, related research likely would have to be completed both prior to and following construction of a particular project to characterize pre- and postconstruction (or operation) conditions. In many cases, the issue of cumulative impacts requires more study, since species vulnerability may result from the interaction of multiple stressors (for example, stressed species' increased vulnerability to disease as a result of changes in climate). Some vulnerability information may be gleaned through a better understanding of particular species' behavior and/or life history. The result of this work would be additional characterizations of species vulnerability for use in impact assessment and other management applications.

BENTHIC AND PELAGIC HABITAT VULNERABILITY TO SPECIFIC STRESSORS

New research to study the effects of various disturbances on benthic and pelagic marine habitats will help form the basis for characterizations of habitat vulnerability. Similar to marine life, research could inform vulnerability assessments within broad categories (e.g., benthic disturbance, water column infrastructure, sound). Furthermore, there could be opportunities to study specific interactions such as pelagic habitats and aquaculture, and seafloor habitats and submarine cables. The result of this work would be additional characterizations of habitat vulnerability for use in impact assessment and other management applications.

⑤

Characterize changing conditions and resulting impacts to existing resources and uses

Climate change was identified as a critical topic requiring additional research, as it is already influencing the distribution and abundance of marine life and habitats and affecting resource-based economies in the Northeast. Research on this topic is being conducted at a rapid pace for various management applications, and results will continue to greatly benefit the interpretation of data and information to support ocean management. Regional experts are engaged in existing research and new efforts that further our understanding of what climate change–driven effects are occurring, and how these affect the distribution, abundance, and resilience of marine life and habitats. These changes will, in turn, result in changes to human activities.

The RPB has identified the following research topics for characterizing climate change and associated impacts:

RECENT TRENDS DUE TO CHANGING CONDITIONS

Fluctuations in ocean conditions, habitats, and species that result from climate change require further study. Maps of the associated shifts in temperature, pH, dissolved oxygen, water column stratification, sea level rise, and species distribution and abundance would support further analyses and decision-making, as would engaging people with on-the-water knowledge and observations. Data products that document and convey trends have been identified as a science priority and should be incorporated into the Portal to supplement current ocean resource and activity data. The result would be an enhanced understanding of how climate change and climate-forcing factors are altering ocean conditions, habitats, and species. Additionally, these results could be incorporated into forecasting models, several of which are already in existence or being developed for the region, to help identify future trends in ocean conditions and, potentially, species' reactions and habitat changes that could result from these trends. There is already a great deal of interest in assessing the results of such information for management use (e.g., to help assess future conditions for decisions with relatively long-term duration—to cover the anticipated life span of ocean development activities).

MARINE LIFE AND HABITAT VULNERABILITY TO CLIMATE CHANGE

There are major gaps in our understanding of the responses of marine life and habitat to climate change. Therefore, assessments of climate change vulnerability are a research priority. Species and habitats can be grouped, ranked, and mapped by climate exposure, vulnerability, or sensitivity to climate change impacts. There is a need to use existing data and information that is routinely collected to characterize, for example, how ocean warming will affect species living at their southern range limits, and how ocean acidification will impact the development and survival of shell-forming organisms. The result of this work would be an enhanced understanding of the vulnerability of different marine life populations and various habitats to climate change for use in various management applications.

CHANGES IN HUMAN ACTIVITY RESULTING FROM CHANGING OCEAN CONDITIONS

There are uncertainties in how human activity and resource use may shift as a function of climate change. For example, more work is needed to characterize changes in the spatial pattern and intensity of fishing activity due to shifts in fish species distribution and abundance; changes in the timing and intensity of recreational uses due to warming; changes in the frequency and intensity of storms or other climate impacts; and changes in tribal use and in habitats/resources important to tribes.

Advance ecosystem-based management by building on previous priorities and also including cumulative impacts and ecosystem services

This final priority outlines additional science and research to further advance an ecosystem-based approach in the region by advancing methodologies that will look more comprehensively at human relationships with the ocean environment.

The five preceding science and research priorities will provide interdisciplinary data and information needed to support an ecosystem-based approach to ocean management. This final priority outlines additional science and research to further advance an ecosystem-based approach in the region by advancing methodologies that will look more comprehensively at human relationships with the ocean environment. Planning discussions on this topic focused on the need to assess cumulative impacts, to understand ecosystem service production and valuation, and to continue work on the IEA Framework that the RPB developed as part of this Plan. Such work in the future would likely involve the continued development and testing of various modeling approaches for understanding and assessing changes in the marine ecosystem and its services, for example, as related to cumulative impacts.

Additionally, policy research is necessary to better understand how existing federal laws and programs can utilize the outputs of the science and research described in the following paragraphs (i.e., to help identify how ecosystem-based management can continue to be advanced).

CUMULATIVE IMPACTS

Many people have identified the need to advance methods to quantify cumulative impacts, including better mapping of stressors, and to investigate the types of cumulative impact considerations in management decisions that could be improved with this information. Cumulative impacts refer to the combination of effects from multiple natural and human stressors on a species, population, or whole ecosystem. Partners in the Northeast and elsewhere have attempted the difficult task of cumulative impact assessment, resulting in the identification of the need to continue developing cumulative impact assessment methods and analyses. Cumulative impact studies at the regional scale could consider the past, present, and future human uses in the Northeast, in addition to changing ocean conditions. Additional considerations for advancing cumulative impact assessments in the region include the spatial and temporal scale(s) of analysis; methods to "translate" human uses into quantifiable stressors; and approaches to qualitatively or quantitatively assess impacts. The result of this work would be a methodology suitable for conducting cumulative impacts assessments in the Northeast that would provide the regional context for specific ocean management decisions.

ECOSYSTEM SERVICE PRODUCTION AND VALUE

More work is needed to understand and incorporate ecosystem service production and value into decision-making. Ecosystem services are the benefits that humans obtain from the structure and function of ecosystems. Assessing ecosystem services demonstrates the value of ecosystem functions (such as the ability of wetlands to buffer coastal properties from storms) that are not otherwise easily quantified or portrayed. This approach promotes ecosystem-based management because ecosystem services are understood using models of the coupled natural-human components of the marine ecosystem. As such, the following individual activities provide opportunities to build on and coordinate with many of the other science and research priorities, given their utility in understanding the coupled natural-human system. The result of this work would be an enhanced ability to model and understand ecosystem services, their value, and the interrelationships between components of the ecosystem and human activities. Ecosystem services research is needed to:

• Develop methods to use existing data and information to characterize the spatial and temporal dimensions of ecosystem services.

• Help users identify decisions that are optimal across sectors.

• Explore how the ecosystem affects human use (i.e., ecosystem services and valuation) and conversely, how human use affects the ecosystem (including cumulative impacts).

• Express outputs in biophysical terms (e.g., biomass lost or gained), economic terms (e.g., dollars lost or gained), social terms (e.g., stakeholder satisfaction or dissatisfaction), or all of the above.

IMPORTANT ECOLOGICAL AREA FRAMEWORK

Continuing work to develop the IEA Framework and to explore options for its use within federal law is a priority. The RPB noted that the development of the Northeast IEA Framework is an iterative and adaptive process. This process includes using the latest data and research to support additional and improved characterizations of the individual IEA components, as described in previous science and research priorities. In general, future work refining elements of the framework itself, and the process for identifying IEAs described in the Plan, will result in the continued consideration of aspects of ecosystem-based management such as ecosystem function, recovery, and resilience. Further development of the IEA Framework that could enhance utility for management includes:

• Continued review of thresholds and other methodological considerations for certain IEA components as new data are available and/or environmental conditions change.

• Agency engagement on the potential uses of IEA components in planning and decision-making.

• Continuation of the adaptive approach recommended by the EBM Work Group by periodically refining methods and components, and reviewing the application of data to the framework.