OCS Study
BOEM 2015-037

Identifying Information Needs and Approaches for Assessing Potential Impacts of Offshore Wind Farm Development on Fisheries Resources in the Northeast Region

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The CFRF and the CCE also wish to acknowledge and express our gratitude to the Bureau of Ocean Energy Management (BOEM) for giving us the opportunity to carry out this important work and for providing the financial support. A special thanks is extended to Brian Hooker, Marine Biologist, in BOEM’s Office of Renewable Energy Programs, for his guidance and enthusiasm.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS AND ACRONYMS

AC	Alternating Current
ADCP	Acoustic Doppler Current Profilers
ASMFC	Atlantic States Marine Fisheries Commission
BACI	Before-After Control-Impact
BOEM	Bureau of Ocean Energy Management
CCE	Cornell Cooperative Extension
CFRF	Commercial Fisheries Research Foundation
CTD	Conductivity, Temperature, and Depth
DC	Direct Current
EFH	Essential Fish Habitat
EMF	Electromagnetic Field
MAFMC	Mid-Atlantic Fishery Management Council
MPA	Marine Protected Area
NEAMAP	Northeast Area Monitoring and Assessment Program
NEFMC	New England Fishery Management Council
NEFSC	Northeast Fisheries Science Center
NMFS	National Marine Fisheries Service
NOAA	National Oceanographic and Atmospheric Administration
OCS	Outer Continental Shelf
WEA	Wind Energy Area

FOREWORD:

The following report summarizes the findings that resulted from a joint effort conducted by the staff of the Commercial Fisheries Research Foundation and the Cornell Cooperative Extension of Suffolk County Marine Program to solicit input on the potential impacts on fisheries resources from offshore wind energy development in three offshore wind planning and lease areas off the coasts of southern New England, New York, and New Jersey, and how such impacts should be assessed. The effort, although done in a relatively short time frame with a limited budget, was able to provide what we hope will be considered very valuable input on these subjects from knowledgeable representatives of the commercial fishing industry, state/regional/federal fisheries managers and scientists, and fisheries researchers in the region. This compilation of comments and recommendations from small group discussions, written responses, and individual interviews by phone, e-mail, and in person is intended to assist with the development of a coordinated, comprehensive, standardized approach to fisheries resources impact evaluation, and serve as an important step in providing the necessary guidance for establishing research and data collection requirements for offshore wind energy developers.

In addition to the compilation of comments and recommendations, this report contains a comprehensive summary of background research as well as a final section drafted by the CFRF staff entitled "Suggested Best Practice Protocols". This final section is based on the input summarized in this report, particularly the input which concerns the research and information gathering needs that pertain to three Wind Energy Areas (WEAs) as defined in Table 1. It is tied directly to the research questions that emerged and is intended to provide assistance to BOEM as guidance and requirements are developed for offshore wind energy developers.

Finally, it should be noted that despite the facts that offshore wind energy development is a new endeavor in this country, and there is a lack of site specific data available to answer key questions concerning fisheries impacts here in these northeast WEAs, the content of this summary report is rich and important. It draws upon the experience and knowledge of those most directly connected with fisheries resources on a daily basis – members of the commercial fishing industry, state/regional/federal fisheries managers, and fisheries researchers from private and academic institutions. It speaks to the need to engage representatives of these groups in a collaborative approach as a comprehensive baseline and monitoring research program is established, the subsequent research and data collection requirements are implemented, and the resultant data is analyzed. Hopefully this report will serve as an important first step in accomplishing that approach.

Peg Petruny-Parker, Executive Director
Commercial Fisheries Research Foundation

EXECUTIVE SUMMARY:

The following report summarizes the findings of a project centered on gathering input on the potential impacts to fisheries resources from offshore wind energy development in three Wind Energy Areas as defined in Table 1 off the coasts of Rhode Island, Massachusetts, New York and New Jersey, and the best methods for evaluating potential impacts. It is important to note that "Wind Energy Area" and the acronym "WEA" used in this report refer specifically to areas as they are defined in Table 1 and do not reflect definitions used by BOEM in differentiating a particular phase of pre or post lease issuance. The Bureau of Ocean Energy Management (BOEM) has issued a total of four leases to two companies in two of the WEAs and is currently gathering information on the Cholera Bank WEA described in this report. Over the course of several months, input was received from members of the commercial fishing industry, fisheries managers, and marine scientists based in the northeast United States through small group discussions, written responses, e-mail correspondence, and phone interviews. The purpose of the project was to assist BOEM as it develops regulations and guidelines for offshore wind energy developers regarding research and monitoring requirements.

The major project findings include the following:

1) Currently, the site specific project data needed to evaluate the potential impacts on fisheries resources in these WEAs is lacking, resulting in uncertainty and speculation;
2) Given what is known about the fisheries resources in these areas, there is general agreement that there will be impacts, but the types of impacts and their significance is uncertain;
3) Robust baseline research and ongoing monitoring utilizing a variety of approaches will be needed to evaluate impacts and determine mitigation measures;
4) Identification of impacts directly attributable to offshore wind energy development activities may be challenging given changes caused by other factors such as climate change, ecosystem dynamics, fishing pressure, and natural interannual variability;
5) Guidance on recommended standard assessment protocols is lacking from existing offshore wind energy development projects;
6) In assessing impacts, attention will need to be focused on species that are commercially or ecologically important, have undergone or are in the process of rebuilding, or are designated as protected or endangered.

In discussing how individual fish and invertebrate species might be impacted by offshore wind energy development, project participants provided the following major points: 1) The species or species groups present in these WEAs, likely to be impacted by development activities, and therefore important to target in research and monitoring efforts include: alewife, American lobster, Atlantic cod, Atlantic herring, Atlantic sturgeon, black sea bass, blueback herring, bluefish, blue mussels, butterfish, haddock, Jonah crabs, little/winter skates, longfin squid, mackerels, mako shark, menhaden, monkfish, ocean quahogs, pollock, red hake, sea scallops, scup, silver hake, spiny dogfish, striped bass, summer flounder, surf clams, thresher shark, tunas, winter flounder, and yellowtail flounder; 2) Habitat changes associated with offshore wind energy facility construction and operation, such as loss of hard bottom and sand wave habitats due to sedimentation and scouring, addition of high-relief habitat around turbines, redistribution/displacement of important spawning, nursery, and foraging habitats, the creation of micro habitats from shading effects, and introduction of novel electromagnetic fields, are likely to impact larval, juvenile, and adult stages of many fish and invertebrate species in a variety of ways; 3) Changes in sea surface and seafloor circulation patterns associated with the development of offshore wind energy facilities could affect patterns of larval drift and settlement, upwelling events and productivity cycles that drive fish production, and sedimentation processes that influence species assemblage structure and trophic interactions; and 4) Increased noise and vibration associated with turbine construction and operation and increased boat traffic could result in increased larval mortality for many fish and invertebrate species, displacement of or interruption to migration patterns and reproductive behaviors, alteration of species distributions, and injury or mortality of fish with swim bladders.

Some respondents emphasized that an adequate understanding of ecosystem structure and trophic relationships on the WEA scale have not yet been developed, but are essential to achieve before moving forward with development activities. Ecosystem-wide changes could potentially stem from the displacement or redistribution of species that play key trophic roles, changes to predator-prey relationships, introduction of invasive species, and alteration of benthic habitats and circulation patterns, among others. Monitoring of indicator species could be a method of tracking ecosystem changes. Concerns were also raised about possible pollution or debris fields resulting from vessel accidents or turbine/pylon damage.

During discussions, some possible mitigation options were mentioned. These included requiring developers to: 1) Avoid placing offshore wind energy structures in critical habitat areas and along migration routes; 2) Constrain the footprint size and construction schedules to minimize disturbance to key species and processes; 3) Reduce potential noise and vibration impacts by utilizing soft start procedures and/or noise abatement measures; and 4) Bury and regularly monitor the burial depth of power cables to minimize exposure to electromagnetic fields.

In terms of a recommended research and monitoring approach to assess impacts, all project participants agreed that it is critically important to conduct adequate baseline survey work in each WEA prior to construction for at least 2-3 years. Pre-baseline research may also be needed to identify critical habitat areas and seasonal species distributions within each WEA in order to develop effective and efficient baseline and monitoring protocols. It is essential that baseline survey work employ methodologies that can be replicated in ongoing monitoring studies once wind energy facilities are constructed and include appropriate control sites, so impacts can be properly assessed. An ideal research program would incorporate the use of different gear types for survey work (otter and beam trawls, pots/traps, fixed nets, and hook and line) and be accompanied by acoustic telemetry, ichthyoplankton sampling, tissue/stomach sampling, visual surveys (habitat cameras), interferometric sonar surveys, and oceanographic observation and modeling (stratification and flow assessments), with data collection occurring during all four seasons.

In general, the input received throughout this project indicated that research questions driving data collection activities need to be clearly identified and agreed upon before development begins. Baseline survey work prior to construction needs to be directed towards developing a more site specific understanding of what species of concern are utilizing these WEAs and how they are dependent on the areas during different times of the year and phases of their life cycles. Ongoing monitoring efforts would be aimed at detecting how development activities alter the environment in the WEAs, and the biological and ecological impacts they produce.

A comprehensive literature review conducted as part of the project indicated that potential impacts of offshore wind energy development on fisheries resources are not well understood, both here in the U.S. and abroad. The multiple phases of development may have varying impacts on the different life history stages of the species present over time. Previous studies indicate the factors that may impact species in these WEAs include: habitat alteration, noise and vibration, electromagnetic fields, scouring and sedimentation, reef effects, introduction of invasive species, lighting effects, ecosystem changes and trophic cascades, and pollution from accidents or structural damage. These factors were also raised in relation to the WEAs discussed by participants in this project.

Regarding the approaches that should be undertaken to assess impacts on fisheries resources from offshore wind energy development, participants highlighted the following major points: 1) The research and monitoring needed should be funded by wind energy developers or wind energy developers and BOEM; 2) Research priority should be given to understanding the significance of WEAs to the reproduction, growth, and survival of species that are commercially or ecologically important, have undergone or are in the process of rebuilding, or are protected or endangered; 3) Data management protocols need to ensure that all resultant data is publicly accessible and available for outside analysis; 4) Pre-baseline studies and planning for baseline survey work should begin immediately for all the WEAs, with actual baseline surveys beginning as soon as possible in the Cox's Ledge WEA; 5) The identification of information needs, setting of research priorities, and implementation of a comprehensive research program should be approached collaboratively, involving members of the commercial fishing industry, fisheries scientists and managers, offshore wind energy developers, and BOEM; 6) Leadership to facilitate, organize, and administer the development of a comprehensive, coordinated research approach and plan is critically needed.

1.0 PROJECT DESCRIPTION

1.1 Overview:

The following report summarizes the findings of an outreach and information synthesis project centered on the subjects of possible impacts to fisheries resources from offshore wind energy development and the best methods for evaluating impacts. Focusing on three wind energy areas as defined in Section 1.2 in the Southern New England/New York Bight area of the Northeast United States, the overall goal of the project was to develop a summary report aimed at assisting BOEM as it develops guidelines, protocols and regulations pertaining to how offshore wind energy development in the northeast will proceed. This includes aspects such as wind turbine micro-siting, design, size, construction schedules, and fisheries resources impact evaluation once offshore wind turbines are operational.

The project was conducted by the Commercial Fisheries Research Foundation, with assistance from the Cornell Cooperative Extension of Suffolk County Marine Program, and focused on three major work components: 1) soliciting, gathering, and summarizing input from fisheries scientists, managers, and members of the commercial fishing industry based in the Northeastern United States who have knowledge about the fisheries resources located in the region, as well as fisheries research techniques and protocols, 2) a background literature review of published articles and reports from previous research efforts on these topics, and 3) the drafting of a list of suggested best practice protocols for evaluating impacts on fisheries resources from offshore wind energy development. The results from the input component, which encompassed small group discussions, written responses, and personal interviews, are summarized under Project Findings, and information uncovered from the literature review is presented under Background Research. The suggested best practice protocols, based on the information received during the project, are provided in the last section of this report.

Knowledge of the distribution and dynamics of fisheries resources is an essential foundation for identifying research questions that will need to be addressed, while expertise and experience in fisheries research methods is an important component in determining how assessment of impacts from offshore wind energy development need to be approached. But as the results presented in the following sections demonstrate, the professional opinions expressed over the course of the project and the results published from previous research endeavors are, for many topics, inconclusive. The following summary report, then attempts to identify the full range of opinions and concerns expressed and research results reported for a number of topics without trying to reflect a consensus finding on any particular issue.

1.2 Focus Areas:

Discussions focused on three specific WEAs located off the coasts of Rhode Island, Massachusetts, New York, and New Jersey (Figure 1, Appendices I, II, III, and IV, http://www.boem.gov/MarineCadastre.gov/). For the remainder of the report, these areas will be referred as the Cox's Ledge WEA, the WEA southwest of Nantucket Shoals, and the Cholera Bank WEA. These were names assigned by the project team to be able to easily differentiate sites for participants and do not reflect definitions used by BOEM in differentiating a particular phase of pre or post lease issuance. The location, size, depth range, bottom types, bathymetric features, and development status of each focal WEA are outlined in the following tables. Although the focus was on the WEA's themselves, discussions regarding fishery resources and impacts were not limited to the specific WEA boundaries. Recommendations are therefore inclusive to areas around the WEAs where vessel traffic and potential cable routes may exist in the future.

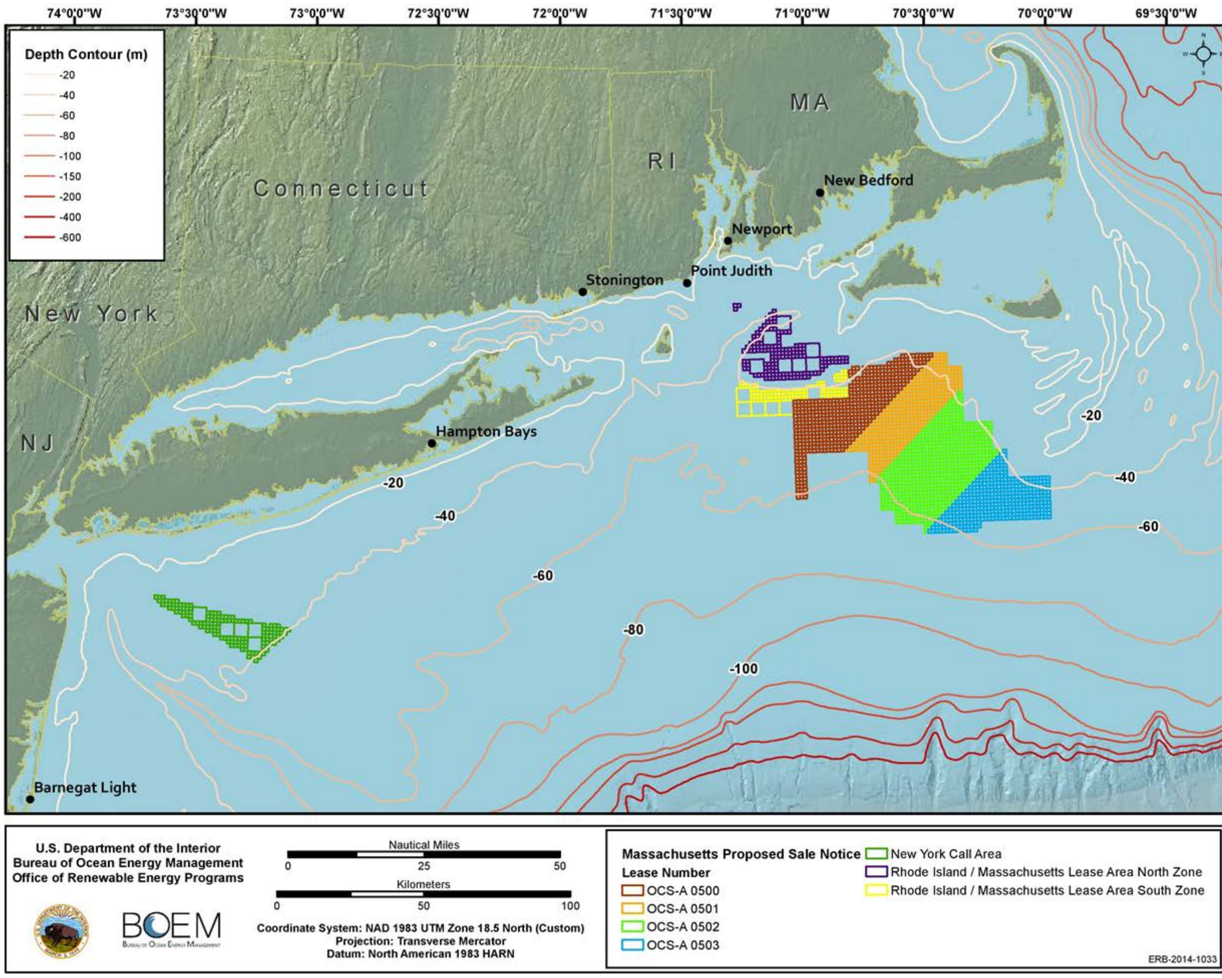


Figure 1. Wind Energy Area Map

Map of the three BOEM wind energy areas in northeast US waters focused on in this project. The Cox's Ledge WEA is indicated in purple and yellow, the WEA southwest of Nantucket Shoals is indicated in red, orange, light green, and blue, and the Cholera Bank WEA is indicated in dark green. Depth contours are in meters. Additional maps are provided in the Appendices I, II, III, and IV.

Table 1. Cox's Ledge Wind Energy Area

BOEM Lease Numbers	OCS-A 0486 OCS-A 0487
Latitude and Longitude Boundaries	North Boundary: 41.298789˚ N South Boundary: 40.952589˚ N East Boundary: 70.826429˚ W West Boundary: 71.293243˚ W

Approximate Distance From Nearest Coasts (Nautical Miles)	9.5 NM South of Newport, RI 12.5 NM East of Block Island, RI 10.5 NM Southwest of Martha's Vineyard, MA
Total Geographic Area	164,750 Acres
Depth Range	17-28 Fathoms 31-51 Meters
Bottom Types (Percentages derived from Northwest Atlantic Marine Ecoregional Assessment, TNC)	Sand 30% Gravel 60% Sand/Silt/Clay 5%
Bathymetric Features	Cox's Ledge and Rhode Island Sound
Development Status	Leased
Lessee	Deepwater Wind New England, LLC.

Table 2. Wind Energy Area Southwest of Nantucket Shoals

BOEM Lease Numbers	OCS-A 0500 OCS-A 0501 OCS-A 0502 OCS-A 0503
Latitude and Longitude Boundaries	North Boundary: 40.139245˚ N South Boundary: 40.586651˚ N East Boundary: 70.021549˚ W West Boundary: 71.054600˚ W
Approximate Distance From Nearest Coasts (Nautical Miles)	12 NM South of Martha's Vineyard, MA 12.5 NM Southwest of Nantucket, MA 24 NM Southeast of Block Island, RI
Total Geographic Area	742,978 Acres
Depth Range	16-35 Fathoms 30-64 Meters
Bottom Types (percentages derived from Northwest Atlantic Marine Ecoregional Assessment, TNC)	Sand 90% Gravel 5% Sand/Silt/Clay 5%
Bathymetric Features	Southwest of Nantucket Shoals
Development Status	OCS-A 0500 - Leased OCS-A 0501 - Leased OCS-A 0502 - Proposed OCS-A 0503 - Proposed
Lessees	RES America Developments, Inc. (OCS-A 0500) and Offshore MW, LLC. (OCS-A 0501)

Table 3. Cholera Bank Wind Energy Area

BOEM Lease Numbers	None To Date
Latitude and Longitude Boundaries	North Boundary: 40.394074˚ N South Boundary: 40.193760˚ N East Boundary: 73.079726˚ W West Boundary: 73.628682˚ W
Approximate Distance From Nearest Coasts (Nautical Miles)	12 NM South of Long Beach, NY 16 NM East of Sea Bright, NJ
Total Geographic Area	81,130 Acres
Depth Range	10-22 Fathoms 18-40 Meters
Bottom Types (Percentages derived from Northwest Atlantic Marine Ecoregional Assessment, TNC)	Sand 45% Gravel 50% Sand/Silt/Clay 5%
Bathymetric Features	Cholera Bank and New York Bight
Development Status	Proposed
Lessee	None To Date

1.3 Project Purpose:

This project was undertaken in response to a realization that potential impacts to fisheries resources in and around these WEAs are uncertain, and it is critically important to engage, at an early stage of development, those most knowledgeable about these resources and with expertise in fisheries research protocols to help direct how potential impacts to fisheries resources should be addressed in pre-construction surveys, construction and operations plans, and post-construction monitoring plans. Up to this point, most discussions have centered on impacts to fishing activities and the possible use conflicts between the fishing and offshore wind energy industries. While there is much to continue to discuss and work through in this arena, there is a growing realization that potential impacts on the resources themselves are equally important to consider, and that consideration needs to occur early in order to minimize potential negative impacts where and when possible. Focusing on impacts to fisheries resources early on is also important in terms of being able to establish adequate baseline information to sufficiently evaluate changes associated with offshore wind energy development and develop effective mitigation techniques for future projects.

1.4 Methodology:

This project was initiated in September 2014 and one of the first steps was developing a strategy and approach to reach out to a wide network of representatives of the commercial fishing industry, fisheries scientists, and fisheries managers knowledgeable about the species present in the focus areas, and how different life stages utilize these locations. This background knowledge was intended to serve as the basis for discussing what the potential impacts from the major phases of offshore wind energy development might be, and the best methods for assessing those impacts once construction and operation phases have begun.

Specific tasks during this initial phase of work included:

- Development of a list of representatives from state/regional/federal fisheries management agencies, scientists from academic and private research institutions working in the fields of fisheries/ecological sciences, and members of the commercial fishing industry familiar with these BOEM wind energy areas under discussion who would be targeted for input (Appendix V).
- Development of an introductory letter to inform targeted participants about the general scope of work and goals of the project (Appendix VI).
- Development of a list of specific questions to be used in soliciting input that were centered on three major topics (Appendix VII):
    1) Which marine fish and invertebrate species may be impacted and how
    2) What types of research should be priority for assessing and possibly mitigating potential negative impacts
    3) What survey methods, protocols, and research approaches should be employed to obtain the needed baseline and monitoring information
-
- Development of an outreach strategy correlated to the list of targeted participants or organizations and comprised of various methods including e-mail correspondence, standard questions, small group meetings, and conference call interviews[1].
- Development of a species of interest list (Appendix IX) for use in stimulating discussions and feedback. The list was created using information from the National Marine Fisheries Service landings data from Statistical Areas 537, 539, and 612 as well as catch information from the National Marine Fisheries Service Northeast Fisheries Science Center's spring and autumn bottom trawl surveys (R/V Bigelow).[2] Species were also added to this list through review of written responses and meeting discussions.
- Compilation of background information to inform project discussions. This included identification, compilation, and review of existing literature (published articles and reports) on the potential impacts on fisheries resources from offshore wind energy development and research protocols. The list of references was broken down based on topics such as noise and vibration, electromagnetic fields, and research protocol recommendations (Appendix X). It also included development of a summary of the top ten species (by volume and value) landed in Rhode Island and New York using 2013 data (Appendix XI).

1.4.1 Outreach Efforts:

Methods used to request input from project participants included:

- Issuance of introductory letters to the complete list of targeted participants.
- Follow up outreach efforts utilizing various forms of communication (individual e-mails and phone calls, small group meetings, written response forms). The first phase of outreach was focused on contacting and soliciting input from scientists based at academic and private research institutions, and managers in state/regional/federal management agencies. This phase was followed by direct outreach to commercial fishing industry representatives, mostly through small group meetings at major ports in

Rhode Island and New York, but also by phone and in person interviews and written responses.

A total of 207 individuals from state, regional, and federal agencies, academic institutions, private research organizations, and the fishing industry were contacted to provide input for this project.

1.4.2 Results Compilation & Synthesis:

Methods used to examine input from project participants included:

- The development of summary notes for each of the small group meetings, conference calls, and individual phone interviews.
- Tracking, review, and summarization of the written responses and e-mail responses received.
- Identification of major concepts and themes that emerged repeatedly, as well as specific points made about species involved, time of the year and type of potential impacts that might occur, connections of potential impacts discussed to certain phases of offshore wind energy development, suggested mitigation methods, and recommended approaches for acquiring needed baseline information and longer term monitoring data to assess impacts. Attention was also given to suggestions regarding the research process, including how research should be approached, who should be responsible for paying for it, how a comprehensive research program might be developed and administered, and how data should be managed. Finally, input was also reviewed with a focus on identifying key research questions that need to be addressed as baseline and longer term monitoring efforts are pursued.
- A reference list was compiled and periodically updated as the project progressed and as background articles were identified and reviewed. As potential impacts were raised in small group discussions or phone interviews, additional references were consulted to help further explain what suggested impacts might be.

2.0 PROJECT FINDINGS

The following sections comprehensively summarize the major findings from all the input gathered from project participants, including representatives from state/regional/federal agencies involved in fisheries management and science, the commercial fishing industry, and academic and private research institutions in the Northeast United States. These findings are organized into the following major topics:

- *2.1 General Findings* – This includes the major consensus points that were repeated in several settings, across all the different formats for input, and by participants representing all the various backgrounds. These general findings relate to both the potential impacts on the fisheries resources themselves as well as approaches to baseline surveys and longer term monitoring.
- *2.2 Species Specific Findings* – This includes comments about specific species of interest and how they might be impacted by various stages of offshore wind energy development. In some cases, comments were received that pertained to likely impacts on groups of species (e.g. benthic, pelagic, forage, highly migratory, etc.), while other comments offered were about specific species known to be present in one or more of these WEAs (e.g. cod, lobster, etc.).
- *2.3 General Species Impacts* – These comments addressed general impacts that have potential to affect all fisheries resources in these WEAs.
- *2.4 Ecological Impacts* – Some participants offered comments about how the ecosystems within these WEAs may be impacted. This level of discussion focused on more than one species, and how the interactions among species might be affected.
- *2.5 Environmental Impacts* – Many concerns centered on how the environment in and around these WEAs might be altered, and the connections between these environmental changes and important fisheries resources. These comments focused on what is known about how species associate with and utilize habitats within these WEAs for reproduction, foraging, growth, and ultimately survival during their various life history stages, and how the different phases of offshore wind energy development may affect these interactions.
- *2.6 Suggested Mitigation* – Some respondents offered suggestions about possible mitigation measures that should be considered as part of the input they gave on potential impacts to fisheries resources.
- *2.7 Suggested Research Protocols* – These comments included general recommendations on research protocols as they relate to all phases of data collection including pre-baseline survey work, baseline surveys, and long term monitoring.
- *2.8 Suggested Research Topics* – This section includes more specific recommendations about theoretical approaches and baseline survey and monitoring protocols organized by major research topics. Specific recommendations addressed such things as the types of survey gear that should be employed, how long and how often sampling should take place, etc.
- *2.9 Suggested Research Approaches* – Input received also addressed the general topic of how research of these WEAs should be approached both in terms of baseline survey work to guide up front development decisions as well as long term monitoring to determine impacts. This input focused on the research process itself, and centered on

questions such as who should be responsible for paying for the needed data collection and analysis, how a comprehensive research program should be developed and administered, and how data should be managed.

2.1 General Findings:

From the very beginning of this project when it was first launched with an introductory letter explaining the scope of work and goals to the last discussion at the end of the input gathering phase, one major point was consistently made: there is a lack of site specific data for each of these WEAs and this information is needed to be able to predict and assess possible impacts of offshore wind energy development on fisheries resources. Respondents relayed that the lack of site specific data is attributable to the temporal and spatial limitations (including an inability to sample hard bottom habitats) of existing survey work conducted along the Northeast U.S. shelf region. Most current survey work is aimed at supporting fisheries stock assessments by determining relative abundance, and not the identification of essential fish habitat and annual cycles of fish distributions in specific locations such as these WEAs.[3] Participants also relayed that the lack of site specific data is attributable to the broad Statistical Area approach used to structure fishing vessel trip reports, and the believed lack of accuracy associated with these required reports.[4]

Those willing to take the time to respond to this input solicitation made it clear that much of what they were offering could be categorized as speculation because of the lack of available site specific studies and adequate field data. Fishermen responders drew upon years of fishing experience in these areas to contribute input on species present at certain times of the year, and how certain fish species might be utilizing these habitats over an annual cycle. Most of their comments were focused on the Cox's Ledge WEA and Cholera Bank WEA because these are areas of high fishing activity. But fishermen were quick to point out that while they have a sense of how these areas are used by fish species, they lack the quantitative data to prove their observations. Scientists responding to questions, in turn, pointed to a lack of published articles and databases that would provide specific information about these WEAs.

Despite the sense that the input being gathered was speculative, there appeared to be general agreement among responders that those in the best position to speculate are those in the region currently immersed in fisheries science, management, and commercial fishing on a day- to-day basis. Furthermore, there appeared to be a general recognition that this type of speculation was a necessary step in developing the right approach to assessing potential and ultimately real impacts of offshore wind energy development on fisheries resources through targeted scientific investigations. There was also a general recognition that although some work has been conducted in Europe, this type of impact assessment is at a preliminary stage in the U.S. Many project respondents also expressed the belief that it is critically important to develop an effective and efficient research approach for these WEAs to serve as a standard for future offshore development projects.

Project participants of all backgrounds also consistently highlighted the point that given what we do know about the fisheries resources currently present in or migrating through these WEAs, and the likely scale of the activity associated with planned offshore wind energy development, there will be impacts. Whether those impacts will be positive or negative, or even significant in terms of species populations in the region is simply unknown. Most respondents speculated that there will be winners and losers in terms of individual species, and most likely a variety of unanticipated impacts. Much will depend on the particular elements of each offshore wind energy development project, including footprint size and orientation, construction timing and extent, and turbine structure and materials. Research will need to be informed by site specific development plans that give as much detail as possible in the early stages of development on factors such as the number and spacing of turbines to be constructed, the methods to be used to secure pylons to the seafloor, and planned methods and routes for cable laying. In turn, these details will need to be integrated with what is known about the species present and the life history stages of those species in order to best plan how to minimize potential negative impacts, maximize any potential positive impacts, and assess impacts during and after construction.

There was general agreement that baseline surveys and longer term monitoring will be essential in order to establish guidelines for development procedures and devise possible mitigation measures. At the same time, this conclusion was accompanied by the observation that appropriate assessment work will be challenging. This observation was based on an acknowledgement that these WEAs have large footprints that host a multitude of species at different times of the year requiring different survey approaches, and that the understanding of ecosystems at this scale has not yet been developed. It was also pointed out that there may be cumulative impacts if a number of WEAs are developed up and down the east coast which could then scale up to affect species at the population level.

In addition, respondents exhibited a general recognition that these WEAs under discussion are located in a region of the continental shelf which appears to be undergoing ongoing change attributable to factors such as climate change, changes in ecological dynamics, and fisheries stock depletion and rebuilding. These regional scale changes may make it difficult to clearly identify local impacts that are directly attributable to offshore wind energy development.

Complicating the challenges associated with conducting appropriate baseline survey work, monitoring, and analysis was the observation that reliable guidance from offshore wind energy development projects already completed in other countries is lacking. Some respondents were familiar with baseline and monitoring procedures conducted by European countries with wind farms in offshore waters. They conveyed disappointment about the way impact assessment procedures were carried out, particularly in regards to baseline information gathering, the relative lack of standard research protocols, and the scarcity of published studies and data. In addition, some of the work that was done for commercially valuable species in these areas may not be applicable to the species of concern occurring in WEAs in the Northeast United States. Those raising these observations pointed to the need to take the time to approach assessment work on potential fisheries resources impacts here in the U.S. carefully and thoroughly.

As respondents discussed and gave input on specific species connected with these WEAs, most agreed that priorities will need to be identified given expected limitations on time and resources. Priority species may need to be identified from multiple perspectives including species that are commercially and/or ecologically important. Consideration must also be given to species with populations in the rebuilding process or which have undergone rebuilding efforts in recent decades, as well as species designated as protected or endangered.

In summary, the general findings that resulted from the input received include the following major points:

- *Currently there is a lack of quantitative, site specific data for each of these WEAs that can be used to establish offshore wind energy development requirements and determine what potential impacts from offshore wind energy development projects will be on fisheries resources.*
- *The lack of available data results in speculation about what the impacts on fisheries resources might be.*
- *Given the existing knowledge of fisheries resources in these areas and the magnitude of activity that will be involved in offshore wind energy development, there is general agreement that there will be impacts on fisheries resources. Whether the impacts will be negative, positive, or significant at a population level is unknown.*
- *Coordinated baseline surveys and ongoing monitoring utilizing a variety of approaches will be essential for mitigation and impact evaluation efforts.*
- *It may be challenging to segregate out the impacts attributable to offshore wind energy development vs. changes brought about in these areas by other factors such as climate change, ecological dynamics, changes in fishing pressure, and natural variability.*
- *Guidance on recommended standard assessment protocols is lacking from existing offshore wind energy development case studies in other countries.*
- *In assessing impacts, attention will need to be focused on species that are commercially or ecologically important, have undergone rebuilding programs or are in the process of rebuilding, or are designated as endangered or protected.*

2.2 Species Specific Findings:

To structure discussions about potential impacts on particular species, project participants were asked to review and comment on a composite species of interest list compiled by the CFRF staff based on data from NMFS (National Marine Fisheries Service) R/V Bigelow spring and autumn bottom trawl surveys and NMFS landings data from pertinent Statistical Areas (Appendix V). Input focused on which species listed within each major category were most important to consider and why, and how various phases of offshore wind energy development might impact certain species. Project respondents were asked to be specific in their responses when possible and include information about the times of the year when and specific locations within the WEAs where impacts might be most pronounced. When comments were received pertaining to possible mitigation measures, they were recorded as part of the input record. Representatives from the Rhode Island Department of Environmental Management Division of Fish and Wildlife noted which species from each category should be given priority concern because of their economic, fisheries management, ecosystem, or life history importance; these species are noted in the sections below. A summary of the comments received organized by general species groups are as follows:

2.2.1 Crustaceans:

Of the crustacean species, those most often mentioned by participants as being prevalent within the WEAs and important to monitor for potential impacts were American lobster, *Homarus americanus*, and Jonah crab, *Cancer borealis*. Rhode Island state managers pointed to American lobster, Jonah crab, and horseshoe crab as being of highest priority to Rhode Island, but horseshoe crab are rarely found in the WEAs considered here.

In terms of lobster, concerns were voiced about possible impacts to multiple phases of the species life history. For example, some respondents voiced concerns about noise and vibrations from construction activities, such as pile driving, possibly damaging or killing lobster larvae or driving female lobsters away from targeted egg release areas to areas less suitable for larval survival. Another possible impact often mentioned was changes in circulation patterns and velocities in and around turbine foundations, and the potential negative impact of planktonic eggs and/or larvae settling outside suitable habitat. Additionally, some respondents voiced concerns about increases in sedimentation from construction activity and scour around turbine foundations that could end up covering hard bottom habitats preferred by lobsters, ultimately affecting their ability to live in these areas and thrive. Others thought structural changes in terms of rubble additions at the base of turbines could possibly have a positive impact by providing suitable new habitat for lobsters.

Both scientists and lobstermen mentioned the trends of female lobsters with eggs aggregating in these WEAs, likely because areas further inshore such as Narragansett Bay and Long Island Sound have warmed and become less suitable habitat. Among RI lobstermen, there is a belief that the productivity of lobster in Narragansett Bay has shifted offshore to places such as Cox's Ledge in the Cox's Ledge WEA because it offers more suitable habitat for spawning and juvenile development. Lobstermen have observed large catches of female egg bearing lobsters on and around Cox's Ledge to the point where they have determined it is not wise to fish there because of the high occurrence of eggers.[5] Lobstermen speculate there are small resident populations of eggers on and around Cox's Ledge that do not migrate with the rest of the population. They also noticed less shell disease on lobsters in this area, in contrast to other areas such as Narragansett Bay.

Previous tagging studies have also shown the lobsters from Narragansett Bay often migrate to and from Cox's Ledge over the course of weeks (Phillips, 2008). Concerns were raised about lobster migration routes being disrupted during cable laying procedures or if cables are not properly buried, or become uncovered during storm events. It was also noted that knowledge about whether American lobsters will be affected by the electromagnetic fields associated offshore wind energy transmission cables is not available. One researcher pointed out that previous research has shown that spiny lobsters can sense electromagnetic fields (Lohmann et al., 1995), but raised the concern that this type of evaluation has not been carried out conclusively for American lobsters.[6]

The Cholera Bank WEA was also noted as being productive for lobster. Fishermen pointed to the importance of maintaining the integrity of these habitat areas as populations of lobster in more inshore areas such as Long Island Sound and elsewhere have either collapsed or declined significantly in recent years.

Jonah crabs were also mentioned as an important species to consider as they currently support a growing fishery. Fishermen noted seeing extremely high numbers of small Jonah crabs present throughout the northern portion of the Cox's Ledge WEA. Possible impacts mentioned were similar to those mentioned for American lobster: possible disruption to migration routes; damage to larvae by noise and vibration during pile driving; possible attraction to or repulsion from cables (electromagnetic fields); drifting of larval forms outside appropriate settlement areas caused by changes in currents; and loss of suitable habitat areas.

Potential impacts to both American lobster and Jonah crabs were thought to most likely occur in the spring, summer, and fall months (May – October) when these species are most active and most likely to inhabit these WEAs in higher numbers.

Respondents also noted a high abundance of horseshoe crabs in the shallow portion of the Cholera Bank WEA.

2.2.2 Shellfish:

In terms of shellfish, sea scallops, ocean quahogs, surf clams, and blue mussels were identified as being of high importance by most participants. Rhode Island managers added waved whelk and moon snails to the list of priority species in this category, but these species primarily inhabit inshore waters not covered by the WEAs.

Species in this group are less mobile than others discussed, but are found in the WEAs year round. Due to their relative immobility, it was thought that potential impacts to these species would include localized mortalities resulting from construction activities.

Sedimentation and siltation effects were also commonly discussed, as most animals in this category are filter feeders. Reducing their ability to feed could reduce growth and survival rates, and in turn affect species higher up the food chain that utilize these relatively sedentary species as food. Blue mussels in particular could be negatively impacted by siltation and it was mentioned that they serve as a key food source for scup and black sea bass, as well as many other fish species. Conversely, blue mussels could colonize the artificial hard substrate introduced by the wind turbine foundation structures and benefit from increased habitat (Joscheko et al. 2008, Background Research Section 3.4.5 Mussels & Barnacles).

The Cox's Ledge WEA was identified by some respondents as being a productive area for juvenile scallops. It was stated that roughly every 10 years there is a massive recruitment event in which recruitment is 2-3 times larger than normal recruitment events for sea scallops. It is hypothesized that during these events, large numbers of sea scallop larvae are released from the Georges Bank stock area which disperses and re-establishes the southern New England and Mid-Atlantic stocks to the southwest. There is concern that the WEA Southwest of Nantucket Shoals and the Cox's Ledge WEA could change water transport mechanisms along this route. In general, there was concern that changes in currents and physical oceanographic mechanisms in and around these WEAs could impair scallop and other shellfish larval dispersal, and therefore, reduce recruitment. Cholera Bank was mentioned as being an important sea scallop fishing area, and for having a high abundance of surf clams which could be impacted by siltation.

2.2.3 Demersal Fish:

There are many demersal fish species that were consistently identified as important to consider in the context of the focal WEAs. Many of the members of the New England groundfish complex (cod, haddock, pollock and various species of hake and flounders), as well as other commercially important species such as monkfish, silver hake (whiting), scup, and black sea bass, were frequently mentioned in discussions and written input.[7,8] Rhode Island state managers included

Atlantic halibut, American plaice, sea raven, American eel, conger eel, sand eel, tautog, red porgy, John Dory, ocean pout, weakfish, cunner, Atlantic sturgeon, and wolf fish in their list of high priority demersal fish species.

Potential impacts on cod were a recurring theme in group discussions and written responses, particularly in the Cox's Ledge WEA. Cod are known to inhabit this area year round, and fishermen relayed that they spawn in the Cox's Ledge WEA in the time period of December to March.[9] Cod are known to aggregate in specific areas to spawn, based upon physical environmental conditions. Cod eggs drift 90 days before hatching and are released in specific locations so that they drift to productive areas and hatch there to maximize chances of survival. Commenters pointed out that it is believed that cod spawn in different areas each year, making it hard to concretely identify and manage their spawning grounds. Potential impacts from offshore wind energy development include damage to eggs and larvae from noise and vibration during pile driving, displacement from important spawning areas, and disruption to annual migrations (cod were reported to migrate along Long Island seasonally, and through Nantucket Shoals southwest to RI Sound beginning in November). Cod might also be attracted to the turbine structures, which could be beneficial for the species by providing complex habitat and potentially novel prey resources.

Haddock, silver hake, and red hake were also mentioned as species that spawn within these WEAs, with silver hake most abundant between 20-35 fathoms throughout the Cox's Ledge WEA. Some fishermen relayed that haddock are believed to spawn in the same areas every year, but targeted research is needed to verify this. Several respondents pointed to potential impacts centered on possible damage to larvae from noise and vibration as well as loss of important habitat, such as soft bottom, gravel, and cobble, which play a role in egg survival. Furthermore, it was relayed that haddock, cod, and winter flounder all spawn in the winter and early spring months, and thus, construction activities, such as pile driving and cable installation, which could result in injurious noise and vibrations or abnormal levels of suspended sediments in these WEAs, should be planned with these spawning seasons taken into consideration.

Demersal fish with swim bladders (e.g. black sea bass) could be negatively impacted from noise vibrations from construction activities if the level is high enough to cause damage to the swim bladders. There was uncertainty from responders about the potential impacts from operational noise once turbines are installed and become operational. It could cause avoidance behavior in these areas or disrupt migration routes as species such as winter flounder move inshore to spawn in late winter/early spring. Some species might leave the area temporarily while others could leave permanently because of noise disturbances. There was uncertainty about whether temporary movement away from these WEAs would impact recruitment rates.

Several responders commented about various flounder species, including summer flounder, winter flounder, and yellowtail flounder, and potential impacts to them in these WEAs. Yellowtail flounder was mentioned as a species likely to lose suitable habitat because of the footprint of the turbines. It was reported that they are present in the southern and eastern portions of the Cox's Ledge WEA year round, exhibit strong preference for sandy bottoms, make extensive east-west cross shelf migrations seasonally, and spawn in the summer months. Fishermen's field observations conclude that summer flounder spawn in the Cox's Ledge WEA around the 30 fathom contour, and they also exhibit seasonal cross shelf migration patterns with the highest abundance in the Cox's Ledge WEA in the late summer and fall months. Winter and windowpane flounder are reported as not traveling as far during migrations as other flounder species, but winter flounder do migrate through the Cox's Ledge WEA during the winter months to spawn inshore. The Mud Hole or Deep Hole area northwest of Cox's Ledge was cited as being very productive for all flounder species during spring and fall month, and the Fingers area adjacent to the Cox's Ledge WEA was also reported as an area where flounder species are abundant.[10] Windowpane flounder are common across the southern New England coastal shelf region at all times of the year.

There was some speculation that flounder species could benefit from reduced fishing pressure if fishing activities are excluded from the wind energy areas. However, other respondents mentioned that this potential positive impact might be offset by a loss of critical foraging habitat for these bottom dwelling fish, disruptions to migration patterns, increased larval mortality from noise and vibration, and the attraction of more predators to the area. These types of potential positive and negative impacts could be important given the fact that some flounder species such as winter flounder are considered to have low stock abundance with rebuilding management plans underway.

Scup is another commercially important species that could be impacted if their migration routes are blocked by construction activities, increased boat activity, or turbidity. Scup migrate from the Hudson Canyon area along the waters south of Long Island to the northeast through the Cox's Ledge WEA to get to their spawning grounds in estuaries. Spawning times in estuaries was relayed to be in the months of April and May. Scup was also mentioned as being present in the Cox's Ledge WEA year round but most abundant from September to December. It was also mentioned that scup have a tendency to congregate around existing tele-communications transmission cables in the area.

Other species mentioned included weakfish, which are believed to be an important species in terms of their trophic role and interactions with other species, and tilefish which are commercially important and are found between 100-300 meters. Specific types of potential impacts on these species were not mentioned.

Highly migratory fish, such as striped bass and Atlantic sturgeon, pass through the Cox's Ledge WEA and WEA Southwest of Nantucket Shoals to feed and spawn in the Bay of Fundy and elsewhere. Construction activities, in particular, were mentioned as having a possible disruption effect on these species. The concern raised was if these types of species are confused and delayed by as little time as two weeks in getting to their ultimate destinations, such as the Bay of Fundy, this could have negative impacts on feeding and spawning cycles.

2.2.4 Pelagic Forage Fish:

The pelagic forage fish species mentioned as being the most important to consider with respect to these WEAs were Atlantic herring, blueback herring, alewife, Atlantic menhaden, and Atlantic mackerel. RI managers also added Spanish mackerel, king mackerel, chub mackerel, American shad, and hickory shad to the list of priority species, but these species are less abundant in the focal WEAs.

Some respondents relayed that anadromous fish species, such as river herring and shad, migrate through the Cox's Ledge WEA and WEA Southwest of Nantucket Shoals in the spring and early summer to get to estuaries such as Narragansett Bay, Great Bay, and the Bay of Fundy, and thus could be negatively impacted by construction and operational activities if they get disoriented or avoid these wind energy areas due to noise and/or vibrations.[11] Short delays in their migrations could result in significant negative impacts to recruitment events and feeding.

2.2.5 Pelagic Predators:

Respondents indicated that a number of tuna species are found within the focal WEAs in the summer months, where they are targeted by sport fishermen. In addition, bluefish and striped bass migrate through these WEAs in spring (April and May) and fall (August and September), but are present in lower abundance in the summer months. Dolphin fish (*Mahi mahi*), cobia, swordfish, wahoo, white marlin, and blue marlin were also noted to be priority species by RI state managers. It was noted that impacts from offshore wind energy development on these species would likely be minimal given the fact that they are wide-ranging, highly mobile, and only present seasonally.

2.2.6 Elasmobranchs:

Project participants identified various elasmobranch species (skates, sharks, dogfish, and rays) as important to consider with respect to WEAs. The species most frequently mentioned were spiny dogfish, little skate and winter skate, mako sharks, and thresher sharks. Thresher sharks and mako sharks, in particular, were mentioned as being important to sport fishermen in these areas in the summer months. Ray species are uncommon in the WEAs considered.

In general, it was noted that large pelagic and coastal sharks (important to recreational fishermen and party/charter boat businesses) are primarily present in these WEAs during the summer months as part of their seasonal migration patterns, but there are not defined mating or nursery areas within these WEAs for these species.

The most commonly discussed potential impact for skates and sharks was the effect of electromagnetic fields (EMFs) from electric power transmission cables on the sensory systems of elasmobranchs. This included concerns related to both inter-array and export cables, although the biggest concern focused on export cables. It is unknown if the electromagnetic fields associated with transmission cables will be detectable by elasmobranchs if the cables are buried. If magnetic fields are detectable, they may attract or repel elasmobranch species (Background Research Section 3.2.2). And if EMFs were to have an impact on elasmobranch behavior (through attracting or repelling), they could disrupt feeding, spawning, and/or migration.

It was noted that white sharks and basking sharks were not on the original species of interest list, but they do pass through these WEAs, mostly in summer months. Following this note, these two species were added to the species of interest list.

2.2.7 Short Lived Species:

One of the most economically important species that could be impacted in these WEAs, which was mentioned frequently by respondents, is longfin squid. Longfin squid spawn in and around all these WEAs in the summer and early fall. Deep Hole and Cholera Bank [12]were mentioned as productive areas for squid, and lobstermen reported seeing squid egg mops in the August to

September time frame at depths around 25-30 fathoms (45 – 55 m) in the Cox's Ledge WEA. Egg mops have also been observed offshore (around and beyond the shelf break) and nearshore (inside the shelf break to the coast). Cholera Bank was mentioned as being a known spawning area for squid. Both longfin and shortfin squid are caught at depths up to 120 fathoms (219 m), but it was noted that longfin squid come up closer to shore in the summer months and consequently may be more susceptible to offshore wind energy development activities during that season. On the other hand, shortfin squid may be much less susceptible to impacts as they are usually found in waters 35 fathoms (64 m) or deeper. Longfin squid have been observed to be particularly abundant between 20-35 fathoms (45-55 m) throughout the Cox's Ledge WEA.

Butterfish are another commercially important species that were mentioned. They are highly mobile, but could be attracted to and congregate around wind turbine pylons or vice versa.

2.2.8 Protected Species:

Atlantic sturgeon were cited as the only endangered fish species in these WEAs that may be impacted. This species migrates seasonally from rivers and estuaries to nearshore marine environments in the fall (around October) and then remain in the ocean until spring (around May) when they return to their native rivers to spawn. Atlantic sturgeon do not spawn every year, and thus, some individuals remain in the ocean throughout the year. Possible impacts to adult sturgeon in the ocean environment would likely be greatest in the fall and winter months and may result from seafloor alterations and noise pollution during construction and operational phases of development, and collisions resulting from increased boat traffic during all phases of development. Larvae, eggs, and juveniles would not be impacted due to their absence within these WEAs.

Also mentioned was the fact that Atlantic sturgeon are listed as Threatened under the Endangered Species Act for the Gulf of Maine and are listed as Endangered in all other Distinct Population Segments (DPSs). Individuals from other DPSs will most likely be present in these WEAs due to the fact that they make long distance coastal migrations. In particular, respondents noted that juvenile Atlantic sturgeon are frequently found in the Cholera Bank WEA, especially in the northern portion.

2.3 General Impacts:

In addition to comments about specific species, project participants also offered a number of general observations about potential impacts to fish and invertebrates in these WEAs. For example, it was pointed out that some species could leave a WEA temporarily, while others might leave these areas permanently. It is difficult to predict whether loss or avoidance of preferred habitats on either a temporary or permanent basis could affect chances of survival of individuals or impact populations by impacting recruitment rates.

Many concerns were voiced in terms of the impacts from the construction stage of offshore wind energy development. Fish and larval mortality, disruption of essential fish habitats, interruptions to migratory patterns at critical life stages, or masking of audio-communications used for sexual attraction were cited as likely consequences from increased noise and vibrations, especially during the construction phase of development when pile driving and increased boat traffic will occur. This stemmed from the fact that so many of the species migrate to or through these WEAs on spring or fall runs, or live in these areas year round.[13] Fishermen raised concerns about the cumulative impacts from offshore wind energy construction projects if they occurred on key spawning grounds at critical times of the year. They worried that entire cohorts and year classes of some species could be eliminated due to multiple construction projects occurring simultaneously throughout spawning seasons. Some respondents also mentioned that spawning in these areas occurs year round by one species or another, and some species have protracted spawning periods spanning several months which range over a large spatial area, making it difficult to avoid all possible impacts.

Cable laying was consistently mentioned in terms of having the potential to impact many species. Increased sedimentation associated with cable installation could impair some species ability to forage effective or avoid predators. If cables are not buried properly or if they do not remain buried, their electromagnetic fields could be disruptive to migratory patterns, feeding and spawning behaviors.

A number of respondents also noted that turbine foundations and platforms could provide high-relief habitat, which may act as shelter or introduce new prey resources for structure-associated species, such as black sea bass and lobster. [14] Scientists were uncertain if this might simply affect the distribution of fish in the area by creating areas of aggregation or if it would increase overall fisheries productivity in the areas. Some mentioned that productivity should stabilize post construction.

Spring, summer, and fall are critical seasons for many of the species present in these WEAs in terms of their spawning, feeding, and/or migrations. However, there are other species for which winter would be a critical season. This leads to the general conclusion that effects may be different but significant at all times of the year. It was mentioned that more needs to be known about essential fish habitat in these WEAs, and how factors such as currents impact species larval dispersal and adult habitat use. On the whole, impacts could be significant for demersal and short-lived species while impacts to pelagic forage species, pelagic predators, and elasmobranchs could be less significant given the wider distribution of these species.

In summary, the comments received about specific species and how they may be impacted by various stages of offshore wind energy development included the following major points:

- *The species most often mentioned as important to consider with respect to the focal WEAs included: American lobster, Jonah crab, sea scallops, surf clams, ocean quahogs, blue mussels, cod, haddock, pollock, red and silver hake, summer, winter, and yellowtail flounders, monkfish, black sea bass, scup, longfin squid, butterfish, spiny dogfish, little and winter skates, Atlantic and blueback herrings, alewife, menhaden, bluefish, striped bass, and Atlantic sturgeon.*
- *The noise and vibrations associated with wind energy facility construction and operation raised concerns about potential negative impacts on several species, including larval mortality, damage to or morality of fish with swim bladders, interruptions to migration patterns and spawning behaviors, and displacement (either on a temporary or permanent basis).*
- *Changes in circulation resulting from offshore wind energy development could advect larvae outside suitable settlement and nursery areas, alter stratification and upwelling dynamics and subsequent productivity cycles, increase sediment suspension and siltation impairing filter feeder growth and survival, particularly for sedentary filter feeders, and alter species assemblages and trophic interactions in and around wind energy areas.*
- *Habitat changes could result in positive or negative impacts to fisheries resources. Potential positive impacts include the introduction of high-relief habitat for flora and fauna to adhere to or congregate around, potentially simulating a reef effect. Potential negative impacts include loss of productive hard bottom and sand wave habitats that are important for many juvenile and adult fish and invertebrates, scouring and siltation around turbine structures and the associated smothering of sessile species, introduction of novel electromagnetic fields with unknown consequences for many species (but especially elasmobranchs), and alterations to key spawning and feeding grounds for many important species.*

2.4 Ecological Impacts:

As mentioned above, one of the general findings related to the challenges of WEA assessment work is the fact that an adequate level of understanding of ecosystems and interspecies relationships at the geographic scale of wind energy areas has not yet been developed. However, participant responses did include comments related to what could be considered as potential ecosystem impacts.

One major concept that was discussed on a regular basis was the introduction of invasive species to these WEAs through increased boat traffic to and from these sites and the establishment of uncolonized habitat (i.e. turbine structures).[15] Invasive species could colonize turbine structures and then use this base as a stepping stone to invade habitat areas surrounding the turbines, to the detriment of native species.

Another ecological concept discussed was the direct and indirect effects of structure and microhabitat changes. These may begin as impacts to species in key trophic roles, which could alter food webs, trophic cascades, and entire ecosystems. For example, negative impacts on primary production and forage fish are likely to propagate up the food chain impacting pelagic predator’s species such as striped bass, bluefish, and tuna. Lower trophic level species such as herring may be of great importance to ecosystem stability.

The addition of rocks or other stabilizing materials around the base of pylons could add protective habitat for lobsters and crabs, and other structure-associated species such as black sea bass, tautog, and cunner could benefit from the increased availability of epifaunal prey growing on turbine structures. Such epifauna could also serve as prey for species such as cod during the winter season.

Pelagic predators moving between habitats could be impacted if they reroute migration patterns to exploit dense prey resources around turbines. Pelagic predators such as tunas, jacks, sharks, cobia, and dolphinfish could be seasonally attracted to the pylons making them more accessible to sport fishermen (i.e. human predators).

Lower down the food chain, an increased abundance of starfish and/or crustaceans may result in a higher consumption of juvenile scallops or other shellfish. Likewise, an increase in pelagic productivity could result in an increase in jellyfish, which are voracious predators of larval and juvenile finfish. It was also noted that an increase in jellyfish in an area could result in a congregation of more sea turtles, which in turn could benefit from the aggregated food supply but could be exposed to an increased risk of encounters with fishing gear.

Overall, predator/prey communities are likely be altered adjacent to wind turbines. Benthic environments disturbed during construction could be re-colonized by species which opportunistically move in after disturbances such as amphipods, capitellid worms and other invertebrates. After construction, organisms using hard substrate (mussels, black sea bass, scup) may increase in the area. On the other hand, epifaunal species dependent on soft bottom habitats (quahogs, sea cucumbers, brittle stars) could be negatively impacted, resulting in reduced prey availability for fish species such as flounders and haddock. Grass shrimp and starfish could also be negatively impacted by sedimentation.

Discussions about how to detect and monitor ecological changes led to the idea of tracking key indicator species. For example, it was mentioned that sand dollars are currently in high abundance in these WEAs and there is no fishery for them, making them a potential species to monitor for detection of changes in their abundance or distribution in these WEAs. It was also mentioned that sea urchins and certain algae species might also be good indicator species to detect changes in the ecosystem.

Cycles of productivity or energy flow in these WEAs could be affected by changes in circulation and mixing associated with wind energy development. Changes in phytoplankton and zooplankton abundance, driven by altered physical conditions, could propagate up the food web to higher trophic levels. Similarly, changes in water flow on the seafloor could result in changes in grain size distribution, which would have significant effects on seafloor fauna.

Even above-water factors, such as the intensity of the lights associated with offshore wind structures, may have impacts on fisheries resources, including the attraction of squid and other light-sensitive fish at night. But while turbine lighting might alter squid and fish behavior in the area, it is unlikely to significantly alter overall ecosystem functioning.

It should be noted that fishermen relayed that they see all the species on the list of species of concern as important because they all have a role in the ecosystem. They did, however, point to blue mussels and starfish as being important prey species.

Finally, it was noted that species currently of low abundance are more vulnerable to impacts than species which are more plentiful.

In summary, comments about possible ecological impacts included the following major points:

- *An adequate level of understanding of ecosystems and interspecies relationships at the WEA scale has not yet been developed.*
- *Invasive species could be introduced to WEAs through offshore wind energy development activities to the detriment of native species.*
- *Direct and indirect effects of structure and habitat changes in these WEAs could manifest into impacts to species in key trophic roles and predator prey relationships.*
- *Monitoring important ecological indicator species could be a method used to track ecological changes.*

2.5 Environmental Impacts:

As respondents offered their input on possible impacts to particular species or groups in these WEAs, they often also made a direct connection between anticipated biological impacts and likely changes in the physical environment that will be brought about by offshore wind energy development. As relayed above, these connections were based on general knowledge of how species relate to and utilize habitats within these WEAs for spawning, growth, foraging, and ultimately survival during their various life history stages, and how the different phases of offshore wind energy development may affect these interactions.

One major likely environmental change cited was the loss of soft bottom habitats, at least temporarily, during construction phase activities. Seafloor disturbance associated with the turbine footprints, the chains and anchors used to stabilize barges and service boats needed for installing the wind energy structures, and jet plowing to create ditches for cable laying were all mentioned in this context.

Pile driving in particular is likely to damage benthic habitat and exceed natural disturbance levels within the WEAs. It was also relayed that chains and anchors used to stabilize installation equipment surrounding a turbine could alter seafloor structure within a 1 mile radius, thus expanding the extent of habitat damage (RI DEM). Furthermore, jet plowing during cable installation will cause large amounts of sediment to become suspended within WEAs and along the cable route to shore. Fishermen voiced concern about areas of suspended sediment (i.e. high turbidity) acting as deterrents to fish, blocking them from normal behaviors and migrations. Suspended sediment would also impair the filter feeding ability of sedentary benthic organisms in the area, if they survived the initial physical disturbance.

Some respondents mentioned that disturbances to complex benthic habitats (gravel, cobble) resulting from construction would likely take extended periods of time (years) to recover, where as soft bottom habitats may recover more quickly (months). The patches of hard bottom in the Cox's Ledge and Cholera Bank WEAs are thought to be important habitat for many species in the area. The edges surrounding hard bottom habitat in the Cox’s Ledge are also key to the growth and survival of many species. The Cholera Bank and the Cox's Ledge WEAs also have numerous sandy bottom areas and it was pointed out that sand waves and sand ridges serve as protective environments for many juvenile fish, such as silver hake. Sand wave features would likely be altered by the installation of turbines and cables, which could have repercussions on many fish and invertebrates in the WEAs.

Scouring at the base of turbines could produce long term habitat changes by increasing turbidity in the water column, blocking sunlight and creating inhospitable conditions for most types of fauna. There was also concern voiced about the effects of increased siltation resulting from scouring in terms of covering over existing hard bottom habitat. There was much discussion about the large degree of scouring observed in European offshore wind farms. Published articles about this general topic of scouring at offshore wind energy sites indicate that scouring is more of a problem in shallower areas than in the deeper areas. Some commenters felt impacts associated with increased siltation might be limited to the construction and decommissioning phases and therefore limited in duration.

There was also general concern voiced by fishermen about possible negative impacts to Cox's Ledge, which they consider to be Southern New England's Georges Bank. They labeled it as being a unique and productive environment accessible to small fishing vessels because of its close proximity to both Southern New England and Long Island ports. Cox's Ledge is viewed by many as the gateway from offshore to onshore environments, both for fishermen during navigation, and for the species which they are targeting.[16] This area in particular exhibits highly diverse bottom types in a relatively small area. This is what makes the Cox's Ledge area so productive for so many different species. Some project participants speculated that turbines sited in deeper areas within the WEA with mud bottom will affect the migrations of lobsters/crabs while turbines sited on rocky and cobble substrate will affect spawning and nursery grounds for many species. Fishermen stated that they consider Cox's Ledge to contain a variety of essential fish habitat areas.

The benthic environment may also respond to changes in fishing pressure if such activities become restricted in these WEAs. A reduction or exclusion of bottom trawling would theoretically result in less disturbance to soft bottom habitats, but the habitat alterations associated with turbine construction/operation may negate such benefits. If enough fishing methods were prohibited in WEAs, these areas could potentially act as pseudo reserves.

Another likely environmental change often mentioned in discussions and written responses was altered circulation patterns within and around WEAs. This was discussed in terms of increased scouring at the base of turbines, as well as changes to the physical oceanographic dynamics in these areas due to shear, drag, and turbulent forces.

It was noted in discussions with scientists that there could be changes in the physical oceanography (e.g. wind, currents, upwelling, etc.) in and around these WEAs as a result of changes in local atmospheric conditions that transfer downward into the water column. This could affect fish species by impacting water transport mechanisms for larvae. For example, scallop larvae from Georges Bank, which typically drift to the southwest, could encounter physical flow field barriers within the WEA southwest of Nantucket Shoals and the Cox's Ledge WEA, resulting in larvae being transported to the open ocean instead of more advantageous areas in and around the WEAs (Tian et al. 2009). It was also mentioned that offshore wind energy development in the Cox's Ledge WEA could reduce water flow across the continental shelf area in this region, impacting nutrient dispersal and potentially productivity regimes. From a more site specific perspective, it was mentioned that prey species may seek out the down current side of structures, where eddies could provide refuge. Tidal flow variability and how it mediates the distribution of small pelagic fish is a factor to consider in an ecosystem context. Also, changes in local water circulation adjacent to turbines and associated structures may impact sand wave structure throughout these areas, potentially altering grain size distribution patterns and the associated benthic macrofauna.

Offshore wind energy development could also result in a situation where wind drag on the sea surface is reduced as energy is captured by the turbines. This could in turn effect stratification in these areas which would affect the degree and timing of primary productivity, as well as egg and larval transport and survival.

Fishermen respondents in particular discussed the relatively high energy environments these WEAs are located in. Some participants indicated that large sand humps have been observed in water depths up to 60 meters in these WEAs. Because of this observation, some fishermen expressed skepticism that transmission cables will remain buried in this high energy environment. Furthermore, a number of participant lobstermen noted that lobster traps in the Cox's Ledge WEA silt up, move, and roll during storms and high intensity weather events, which also provides evidence of a highly dynamic environment in these areas. This high energy environment was mentioned in terms of the possibility of uncovering power cables, even if they are buried 6 feet in the sediment. Fishermen also noted that existing tele-communication transmission cables in the area have been uncovered and subsequently encountered by fishing gear. There are concerns about conflicts with hydraulic clam dredges which penetrate sediment several feet. The uncovering of cables raises concerns about the effect of electromagnetic fields on species such as elasmobranchs, lobsters, and scup, as previously explained.

Erecting structures in these environments could potentially result in reef effects by providing an added surface for epifaunal growth and aggregation of fish into these areas. Questions were raised about whether this effect might result in simply a relocation of fish or an increase in biomass. It was noted that the bottom type and currents around foundation pylons will partially determine whether there is an artificial reef effect. Some respondents speculated that the introduction of hard structure in these WEAs could increase habitat and benefit species that prey on taxa which utilize high relief, hardbottomhabitats. At the same time, it could also alter interactions between both prey and predator species.

In addition to reef effects, foundation pylons and turbines may also have a shading effect, as these structures provide patches of shade that may be attractive to various life stages of fish and invertebrates, as has been shown in coral reef environments. This shading effect may impact how organisms are concentrated and interact (i.e. predator-prey dynamics). For example, pelagic predators may benefit from more efficient feeding in shaded areas around turbines.

Another potential environmental impact of offshore wind energy development of grave concern to many participants was that of oil and chemical spills resulting from accidents or storm damage. This was spoken of in terms of coming from either the vessels servicing the facility, vessels passing through the facility, or damage to the turbine structures from vessels or storms. Respondents pointed to the potential negative impacts from pollution and debris fields on many species if damaging accidents occurred in the offshore wind energy facilities (vessel collisions, turbine failure, and destruction from storms, etc.).

Miscellaneous comments about other possible environmental changes resulting from offshore wind energy development included concerns about the interactions with offshore wind energy facilities and local weather conditions such as increased in fog, and possible interference with weather radar or data collection systems that rely on satellites. The decommissioning phase raised concerns about environmental impacts stemming from turbine materials that may be left on the seabed for extended periods of time.

Finally, several respondents pointed out that determining which environmental impacts are directly attributable to offshore wind energy development may be challenging.This is because the northeast region is undergoing widespread environmental change due to climate change and natural variability. The local-scale data to substantiate and determine the magnitude of these changes, however, is currently lacking.

In summary, major observations about likely environmental changes in these WEAs included the following:

- *Offshore wind energy development in these WEAs will likely produce a number of alterations to the physical environment within and around these sites. Major impacts discussed included: changes to bottom habitats, sedimentation patterns, circulation dynamics, and pollution resulting from accidents. In turn, the potential impacts to fisheries resources were often tied to such changes in the physical environment.*
- *New habitats might be created from the introduction of high relief turbine structures, which will likely alter species distributions and interactions.*
- *Determining what environmental impacts are directly attributable to offshore wind energy development vs. climate change and natural variability may prove to be difficult given the lack of WEA-scale data.*

2.6 Suggested Mitigation:

Respondents found that given the uncertainties in identifying the likely impacts to fisheries resources in these WEAs, it was difficult to identify and offer suggestions about specific mitigation techniques. All felt strongly, though, that the first and most important step in developing mitigation techniques should be the completion of thorough baseline research. Some specific mitigation ideas were mentioned, and these included the following:

- *Habitat Protection*: From the start, all efforts should be made to locate offshore wind energy facilities and transmission cables in areas that are not important migration corridors, foraging grounds, spawning grounds, or nursery grounds. This would include:
    - Avoiding developing wind energy facilities in areas that act as critical seasonal thermal refuges important for the settlement and early survival stages of species such as flatfish and skates. Particular attention should be given to vulnerable species, such as yellowtail flounder, winter flounder, and cod, as disrupting their spawning activities or nursery habitats could have population-threatening effects.
    - Siting turbines, when possible, in areas where ecological impacts would be minimized and using materials and procedures that are most likely to have

positive impacts. For example, it might be useful to add high relief supports to the turbines to provide new, highly complex habitat.
  - Considering seasonal circulation patterns and their ecological functionality, when sites are chosen for wind energy facilities. Developers should be required to install current measuring devices (ADCPs) on turbine platforms within each wind energy area.
  - Considering the use of floating turbine foundations to minimize sedimentation impacts.

- *Footprint Size*: Negative impacts to benthic habitat should be reduced by constraining the size of construction areas within WEAs. The impacts to benthic communities and sessile macrofauna (sea scallops) will be difficult to mitigate, unless revised WEA footprints are considered.
- *Construction Timing:* Careful consideration should be given to the timing of construction, so as to avoid disrupting spawning behaviors and migrations patterns. In both the Cox's Ledge and Cholera Bank WEAs, the impacts on many species would likely be minimized if construction were to take place in the wintertime (December-March).
- *Reducing Noise and Vibration Impacts*: A soft start up procedure should be required during pile driving to lessen noise and vibration impacts. This would enable species to acclimate and move away from the noise before the noise reached levels that could cause damage to tissues such as swim bladders or mortality to larvae. Requiring the utilization of noise abatement measures such as bubble curtains as a means to reduce noise impacts would be another method to reduce negative impacts of pile driving noise.
- *Electromagnetic Fields*: In terms of potential EMF impacts, all efforts should be made to shield transmission cables and use deep-installation techniques to reduce electromagnetic fields exposure to species on or near the seafloor. Burying cable lines and continuous monitoring to ensure cables remain buried during operation should be required.
- *Facility Design*: Developers should be required to carry out modelling studies to determine the turbine spacing and configurations that would have the least detrimental impacts to the environment and fisheries resources in the area (i.e. avoid putting a picket fence up across the continental shelf by breaking up turbines in different configurations). Adequately sized and appropriately oriented corridors in the offshore wind energy facilities should be required to allow currents, eggs, and larvae to flow normally.

In summary the major mitigation options mentioned included the following:

- *Avoid placing offshore wind energy structures in critical habitat areas and migration corridors*
- *Use materials and layout designs conducive to minimizing negative impacts*
- *Reduce noise and vibration impacts by requiring soft start procedures and/or bubble curtains*
- *Constrain the footprint size and construction schedules to minimize negative impacts*
- *Require the burying and ongoing monitoring of power cables to reduce electromagnetic fields*

2.7 Suggested Research Protocols:

A common concept expressed in meetings, interviews, and written responses throughout this project was a critical need for robust research programs in each of these WEAs prior to the construction of offshore wind energy facilities in order to be able to assess the impacts of such activities on the fisheries resources across the Northeast U.S. continental shelf. Unanticipated impacts are likely to occur and, thus, a holistic approach to baseline research and ongoing monitoring is required to detect these changes.

An ideal research program would incorporate the use of trawls (otter and beam trawls), pots/traps (lobster/fish), fixed nets (gill nets), acoustic telemetry, ichthyoplankton sampling, tissue/stomach sampling, visual surveys (habitat cameras), interferometric sonar surveys, and oceanographic observation and modeling (stratification, flow), and data collection would occur during all four seasons. In connection with development of offshore wind energy structures, a research program to assess impacts on fisheries resources would be divided into three temporally distinct phases: pre-baseline research, baseline research, and ongoing monitoring.

General input received regarding these phases was as follows:

2.7.1 Pre-Baseline Research:

- Pre-baseline research, including species assemblage and habitat surveys, is needed to effectively develop appropriate sampling protocols and sampling locations for baseline research and ongoing monitoring programs.
- Seasonal pre-baseline species assemblage surveys (trawls/traps) should be conducted to assess what species are present within these WEAs throughout the year. This information, in turn, should be used to determine the most effective sampling schedules, gears, and designs for extended research programs.
- Habitat surveys should also be conducted prior to the initiation of baseline and ongoing monitoring research programs so that sampling stations can be stratified and selected to cover all habitat types.
- A statistical power analysis should be conducted early in the research planning phase in order to determine appropriate sampling densities and distributions that are needed to detect changes in species distributions, interactions, and environmental conditions (Peterman 1990). The results of such an analysis should be used to refine sampling protocols for baseline research and ongoing monitoring to maximize ecological change detection capabilities.
- Such pre-baseline research will enable the identification of likely ecological and economic effects of offshore wind energy development and the types of mitigation strategies available. The scope of mitigation needs and costs can then be addressed as specific impacts are identified by ongoing monitoring efforts during construction and operational phases.

2.7.2 Baseline Research:

- Robust baseline research programs will be critical to developing an understanding of the fisheries resources ecosystem at the local scale of offshore wind energy developments.
- A minimum of three years of baseline research prior to the construction of offshore wind energy facilities, including fish/invertebrate surveys, trophic structure analysis, habitat surveys, and oceanographic monitoring, is needed to assess existing spatial and interannual variability within these WEAs and to detect future changes.
- It is critical that baseline research be conducted throughout the year to assess seasonal patterns and identify potential mitigation techniques. If year-round surveys are not feasible, baseline research should at least be conducted in the spring, summer, and fall.
- Baseline survey approaches need to be replicable during construction and operational phases of offshore wind energy development in order to facilitate comparisons that have the greatest statistical power to detect change. Thus, otter trawl surveys, a widely used sampling technique, should not be exclusively employed for baseline surveys, as turbines and cables may prevent the use of otter trawls after construction.
- Specific locations, sample sizes, and effort allocation for sampling will need to be addressed within the context of specific WEAs as well as the need to address cumulative (i.e. regional) ecological effects.
- To maximize the efficiency of survey implementation, at least a preliminary site plan will be needed so that changes in station locations due to installation of infrastructure are minimized (or at least incorporated into the statistical design for sampling during construction and operation).
- In all cases, it will be important to designate control sites that are ecologically similar to the construction site so that Before-After Control-Impact (BACI) studies can be properly conducted. Control sites should have similar environmental conditions and species compositions as the WEA and should be also far enough away from the construction site so that they will not be impacted by offshore wind energy development.
- A major goal of baseline research should be to identify mitigation techniques that are applicable prior to construction, such as alternate WEA footprints, turbine anchoring techniques, or cable routes that will minimize negative impacts to fisheries resources.

2.7.3 Ongoing Monitoring:

- It is essential that baseline research programs and protocols be carried through the construction and operational phases of offshore wind energy development, with additional sampling efforts five and ten years after construction to assess long term impacts to fisheries resources.
- In general, an ability to parse regional scale changes (e.g. due to increased temperature) from local scale effects due to the impacts of offshore wind energy development will be key to assessing impacts and predicting effects of future offshore wind energy development.
- Efforts should also be made to examine the population level effects of fisheries

exclusion from the wind energy areas.

In addition to these general recommendations for pre-baseline, baseline, and ongoing research, respondents also provided specific suggestions for focal research topics and their associated research protocols. The research topics consistently identified as critical to address in offshore wind energy research programs include: fish and invertebrate population structure and distribution, fish and invertebrate larval ecology, protected species, trophic structure, spawning behavior, habitat, oceanographic conditions, noise and vibration, and electromagnetic fields. The research needs and suggested protocols for baseline surveys and ongoing monitoring for each of these research topics are summarized in the following section.

2.8 Suggested Research Topics:

2.8.1 Fish & Invertebrate Population Structure & Distribution:

Research Needs:
Responses from academics, managers, and fishermen alike asserted that it is critical to assess how the composition and distribution of fish and invertebrate communities change with the installation and operation of offshore wind energy infrastructure. This includes infauna (primarily as prey resources for mobile fauna), epi- and emergent-fauna (primarily as shelter and prey for mobile fauna), and demersal and pelagic fish and invertebrates (as ecologically and economically important species). Project participants pointed out that changes in fish community structure will likely result from the introduction of wind turbine structures, extending from the seafloor to the surface. Furthermore, changes in grain size distribution across the seafloor, mediated by alteration of the flow field (i.e. scouring), will likely have significant effects on seafloor fauna and those mobile species with habitat-specific patterns of distribution. In the three WEAs under consideration, some respondents speculated that lobster/crab productivity might be increased by the added structural complexity of the wind power sites, while implications for flatfish and skates could be severe if the WEA locations are consistent with critical seasonal thermal refuges needed for settlement and early survival. Because of these unknown impacts, most respondents felt that monitoring the fine-scale spatial structure of fish and invertebrate communities within and around WEAs throughout the development process will provide critical insight and facilitate predictions of environmental impacts of future offshore wind energy proposals.

Baseline Research Protocols:
In order to address the research needs identified under this topic, the following baseline protocols were suggested:

- All fish and invertebrate sampling should be conducted seasonally (spring, summer, fall, winter) for a minimum of three years prior to construction.
- Sampling for infauna should be conducted via triplicate (and up to 10) grab samples in each lease block, with grab sub-sampling used to increase statistical power. Grab sample products should include infaunal species composition and abundance with interpretive products for spatial variation in infaunal community composition, species diversity, functional diversity, taxonomic diversity, and measures of species and community rarity.

- Sediment profile imagery would provide additional value in regards to vertical position of fauna, animal-sediment interactions, and sedimentary habitat characteristics.
- Sampling for epi- and emergent-fauna should be conducted with high-resolution still and video seafloor imagery (still camera normal and oblique angle to the seafloor; video oblique angle to the seafloor) within each lease block. Paired lasers for each camera should allow for calibration of image field-of-view and video transect path width. Still imagery products should include percent cover or density of fauna and derived products as listed above. Sixty still images per lease block is the minimum effort required to adequately sample local diversity. More samples are needed in areas of high habitat heterogeneity. Oversampling during baseline assessments will allow calculation of sample sizes needed for ongoing monitoring.
- Sampling for fish and macrofaunal invertebrates should be conducted with multiple approaches to ensure adequate representation of all species groups and ecological components potentially affected by offshore wind energy development, including the following:
  - Bottom trawl sampling to assess seasonal community structure, size-age structure of fish populations, and variation in reproductive states for late juvenile and adult fishes and macrofaunal invertebrates.
  - Beam trawl sampling with fine mesh to assess seasonal community structure and recruitment patterns of benthic fishes and invertebrates, particularly early juvenile stages (beams trawl more effectively sample young-of-the-year fishes than otter trawls)
  - Split-beam hydro-acoustic surveys to assess seasonal distributions of mid-water fishes, especially small pelagics that function as prey species for higher trophic level predators.
  - Mid-water trawls for identification of target species in hydro-acoustic surveys.
  - Ventless trap surveys to assess seasonal population structure and reproductive patterns of lobster, crab, and fish species poorly sampled by trawl surveys (black sea bass, cunner, conger eels).
  - Hook and line surveys to assess seasonal distribution of highly migratory species, such as tuna, bluefish, striped bass, and sharks.
  - Acoustic telemetry to assess the associations, re-distribution, and migratory patterns of mobile fish and invertebrates (lobster), with acoustic listening arrays located within and around each WEA.
  - Gill net or trammel net surveys could be used to supplement the aforementioned approaches and further assess seasonal population structure and reproductive patterns of benthopelagic predators (monkfish, dogfish, skates).
  - Spotter plane surveys could also be used to track the locations, number, and biomass of menhaden schools.
- The gear employed for baseline research should be tied to the types of species expected to be in a given area at a given time of the year, as determined by pre-baseline research.
- Specific gear designs (net dimensions, configuration, mesh size, trap dimensions) and sampling protocols (tow length, soak time) should be developed with input from the commercial fishing industry, and should strive to maintain consistency with ongoing regional-scale projects, such as the Virginia Institute of Marine Science's North East

Area Monitoring and Assessment Program (NEAMAP) and Southern New England Cooperative Ventless Trap Survey.
- An additional two years of baseline research (for a total of five years) is recommended for the assessment of spatiotemporal trends in the lobster population, given the life history of this species and the data requirements for modeling.
- Survey locations should be selected to provide coverage of lease blocks, representative habitat types, depths, and oceanographic conditions (as determined by pre-baseline research), while avoiding locations that will be inaccessible due to direct effects of construction.
- Control stations, located far enough away from the WEA to be free from offshore wind energy development effects, are also important to include in the sampling design.
- Additional stations for mobile sampling gear could include a wider buffer around the project area, based on species and life history attributes that may vary in the area of the project site.
- All data should be collected in a way that can be combined, compiled and archived with existing state and federal survey, fishery dependent, and biological databases.
- The Northeast U.S. region has several surveys that target large juvenile and adult fish and invertebrates, including the Northeast Fisheries Science Center (NEFSC) bottom trawl and scallop surveys and the NEAMAP survey. Such existing sampling programs should be leveraged, with analysis of data from within and around WEAs. The spatial scales and sampling designs of these programs, however, are not sufficient for assessing offshore wind energy development impacts on fisheries resources. This data, however, will be critical in detecting regional-scale changes in fish community structure.
- The NOAA Habitat Suitability Model may be useful to analyze these areas.

Ongoing Monitoring Protocols:
- All of the approaches listed above should continue during construction and operation to enable an assessment of fish and invertebrate population structures and distributions before and after the offshore wind energy facilities are in place.
- The existing NEFSC and NEAMAP surveys will likely be prevented from sampling within WEAs due to structural barriers and gear restrictions, but these programs should continue around these WEAs to assess regional changes to fish and invertebrate populations.
- Additional components that should be incorporated in ongoing monitoring include:
  - Additional survey stations that encompass elements of the disturbed natural landscape and structural components of the energy installation (e.g. disturbed trenches for cables, buffer zones around structures, anchor surfaces, platform legs and related components). Particular attention should be paid to inclusion of horizontal and vertical surfaces across the depth range of structures.
  - Use of active acoustics (side-scan, DIDSON and similar systems) to assess use of infrastructure by small and large pelagics.
  - Use of passive acoustics to monitor noise impacts and effects of background biological soundscape on fish and invertebrate distributions.
  - Due to the nature and proximity of offshore wind turbine structures, it will likely be necessary to employ fixed gear surveys (traps, hook and line, gill

net), visual surveys (video), or beam trawl surveys rather than otter trawl surveys for ongoing monitoring within WEAs. This is essential to consider when developing baseline research programs and protocols.

2.8.2 Fish & Invertebrate Larval Ecology:

Research Needs:
Respondents concluded that construction and operation of offshore wind energy facilities have the potential to impact all life stages of species that occupy offshore wind energy footprints and the surrounding waters. Thus, it is critical to understand what life stages of what species occupy each wind energy area, what proportion of the population for each life stage occupies the affected area, and whether the affected area is key to species survival.

Baseline Research Protocols:
The major baseline research protocols suggested under this topic included the following:

- Ichthyoplankton surveys for larval assemblage and distribution should be conducted throughout the year for at least three years prior to construction.
- Ichthyoplankton sampling (bongo and manta tows) should be conducted in all lease blocks as well as a control area that is far enough from the WEA so as to not to be effected by offshore wind energy facility development.
- The existing NEFSC Ecosystem Monitoring Program (ECOMON) collects zooplankton and ichthyoplankton samples, but sampling density and frequency within the Cox's Ledge and Cholera Bank WEAs are sparse. The data from these surveys, however, will be useful in tracking regional changes in ichthyoplankton communities associated with offshore wind energy development.
- Beam trawls should also be used to assess the abundance and distribution of recently settled juveniles within and around these WEAs throughout the year for at least three years prior to construction, with sampling locations within each lease block as well as in a designated control area.

Ongoing Monitoring Protocols:
In terms of ongoing monitoring it was suggested that ichthyoplankton surveys and beam trawls should continue during construction and operation, with additional sampling five and ten years after offshore wind energy facility construction to assess long term impacts to larval communities.

2.8.3 Protected Species:

Research Needs:
Input received identified Atlantic sturgeon as the only protected species that utilizes the WEAs under consideration and may be impacted by offshore wind turbine construction and operation. More specifically, the noise pollution associated with the construction and operation of offshore wind energy facilities is likely to affect the movement of Atlantic sturgeon that are within audible range. Also, Atlantic sturgeon are bottom dwellers that may be negatively affected by disruption to the benthos associated with offshore wind energy development. Existing Atlantic sturgeon research within and around WEAs is very limited, with available information derived

from coastal mark and recapture programs and federal observers. Such information is insufficient for predicting and assessing the potential impacts of offshore wind energy development on Atlantic sturgeon, and, thus should be supplemented by targeted research within each WEA.

Baseline Research Protocols:

- Hydro-acoustics (including DIDSON and split-beam) and acoustic telemetry should be used to assess the seasonal distribution of Atlantic sturgeon within and around proposed wind energy areas for at least three years prior to construction.
- DIDSON and split-beam surveys would be best for assessing aggregate use of WEAs by Atlantic sturgeon, provided that species-specific acoustic signatures can be readily identified.
- Telemetry would be best for monitoring individual movement patterns within and around WEAs. Telemetry receivers would also provide information about how other tagged fish/invertebrates (associated with other previous and present research programs) utilize these WEAs.

Ongoing Monitoring Protocols:

- Hydroacoustic surveys should be continued through the construction and operation phases, with additional sampling conducted five and ten years after construction, to assess longer-term changes in the movement and distribution of protected species.
- Once acoustic listening arrays are developed for baseline studies, they should also continue to be used through the construction and operation phases of offshore wind energy development to document changes in Atlantic sturgeon movements.

2.8.4 Trophic Structure:

Research Needs:
During the discussions, it was pointed out that offshore wind energy construction and operation will likely influence direct and indirect species interactions (predation, competition, facilitation, parasitism), coincident with changes in the composition and distribution of local fauna and their habitat. Furthermore, with security zones around offshore wind energy infrastructure producing de facto marine reserves, shifts in the direction and strength of species interactions are likely to occur. On the other hand, it was also pointed out that the effects of reserves on species interactions may be counterintuitive. For example, increases in predators due to augmentation of hard substratum habitats could reduce survivorship of new recruits (e.g. black sea bass predation on juvenile groundfish; rock crab on sea scallop). Furthermore, the trophic subsidies to species (e.g. benthopelagic omnivores) that prey on taxa enhanced by infrastructure habitat (e.g. epifauna) could exhibit enhanced growth and fecundity, but may also minimize competitive interactions between both prey and predator species. Respondents consistently pointed out that while it may be essential to assess the trophic structure and foraging behavior of fish and invertebrate communities within and around WEAs prior to and throughout offshore wind energy development in order to understand, predict and mitigate potential ecological impacts, it will likely be challenging to achieve because current understanding of ecological relationships at this scale are not fully developed.

Baseline Research Protocols:
Input regarding suggested baseline research protocols aimed at understanding possible ecological impacts on fisheries resources included the following:

- Existing trophic interactions should be assessed via carbon and nitrogen stable isotope analysis, stomach content analysis, and benthic faunal sampling (i.e. seafloor grabs, epi-benthic zooplankton surveys).
- Stable isotope analysis is a powerful tool for assessing trophic dynamics in fisheries ecosystems, with nitrogen stable isotopes indicating the time-integrated feeding histories and trophic positions of consumer species and carbon stable isotopes revealing the relative importance of different basal resources (i.e. phytoplankton, benthic macroalgae) in supporting fish production.
- White tissue (stable isotope analysis), stomach (gut content analysis), and benthic grab samples should be taken from locations both within and outside the proposed wind energy areas to facilitate before and after construction/operation comparisons that have sufficient statistical power to detect change.
- Seafloor grabs and epi-benthic zooplankton surveys are essential in assessing the existing food resources available for consumer species.
- Trophic analyses should be carried out seasonally for a minimum of three years prior to construction to fully assess seasonal trends and interannual variability. Fish stomach content analysis, on the other hand, provides a direct measure of predator consumption and, thus, can be used to identify specific trophic linkages (i.e. predator-prey relationships).
- Sampling priority should be given to species of ecological and economic importance, while ensuring that all species groups are represented (planktivores, benthivores, detritivores, omnivores, crustacean eaters, and piscivores).
- Determining the nutritional value and relative importance of different prey groups and habitat types should be a major goal of trophic analyses.
- Collection of tissue and stomach samples can be incorporated into other field programs, including mobile and fixed gear surveys.

Ongoing Monitoring Protocols:
In terms of ongoing monitoring protocols to assess potential ecological impacts, the following points were made:

- All of the approaches described above should continue during the construction and operation phases of offshore wind energy development, as well as five and ten years after construction to assess long-term changes in trophic structure.
- Additional elements that should be included in ongoing monitoring programs for trophic structure include:
    - Additional sampling stations that encompass elements of the disturbed landscape and structural components of the energy installation, including cable trenches, scouring zones, and turbine anchoring platforms.

2.8.5 Spawning Behavior:

Research Needs:
Both scientists and fishermen discussed how critical it is to understand how offshore wind energy construction and operation impact spawning activities, particularly for species that have already been shown to use these WEAs as spawning grounds (Atlantic cod, Atlantic sea scallop, squid, and yellowtail flounder). They pointed out that many species select spawning grounds for specific seafloor and oceanographic conditions that are likely to be altered by offshore wind energy development. Thus, it is essential to develop an understanding of which species utilize WEAs for spawning activities and why, in order to be able to predict and mitigate potential impacts to fish and invertebrate populations.

Baseline Research Protocols:
In terms of assessing possible impacts on spawning activities, suggestions about baseline survey work included the following:

- Baseline research regarding spawning activities should strive to identify which species are dependent on these WEAs for spawning as well as what environmental conditions make the WEAs favorable for spawning activities.
- A combination of acoustic telemetry and whole-fish sampling (method depends on target species) should be used to assess the spawning activities of individual species within these WEAs for a minimum of three years prior to construction.
- Coincident habitat mapping and oceanographic sampling should be used to assess the environmental conditions associated with spawning activities.
- Existing studies on spawning activities and habitat preferences could help narrow sampling windows.

Ongoing Monitoring Protocols:
For ongoing monitoring it was suggested that all of the approaches described under baseline monitoring should continue during construction and operation phases of offshore wind energy development. In addition to acoustic telemetry, side-scan sonar and DIDSON could also be used to assess the use of infrastructure by spawning species, particularly as other sampling techniques are impeded by the offshore wind energy field.

2.8.6 Habitat:

Research Needs:
All respondents relayed that construction of offshore wind energy facilities will undoubtedly alter natural habitat, making it critical to assess the extent to which WEAs overlap with key habitat for fish and invertebrate species. In addition, many respondents felt it is important to understand how key habitats for fish species will move over the coming decades or century (due to climate change), and whether these movements conflict with other offshore development plans. Assessing the amount of seabed disturbance is of particular importance because many fisheries resources species are bottom dwellers that may be negatively affected by disruption to the benthos. Thus, it was suggested that research programs be designed to examine potential use of the hard structure habitats created by the construction of the turbines, potential impacts to the species that use unconsolidated sediments as nursery areas, and potential effects on changes in

community structure to the ecosystem resulting from habitat changes. For example, fish and invertebrate community composition in sand habitat, which comprises the majority of the Cox's Ledge and Cholera Bank WEAs, will likely change when turbine foundations are installed. Thus, habitat research was deemed essential in developing an understanding of the effects of introducing highly structured turbine foundations (hard-bottom habitat), scouring zones (disturbed habitat), and other unforeseen habitat alterations on the fisheries ecosystem and developing mitigation techniques to minimize impacts.

Baseline Research Protocols:

In assessing habitat changes and consequent impacts on fisheries resources, the input received regarding baseline research protocols included the following recommendations:

- In general, baseline habitat research programs should aim to assess the distribution and significance of different habitat types, particularly those that act as settlement and juvenile nursery areas, foraging grounds, and spawning areas for fish and invertebrate species.
- Full coverage multibeam bathymetry and backscatter (via interferometric sonar) should be collected within and around WEAs to assess variability of sediment structure and direct more detailed habitat and macrofaunal assemblage surveys (underwater video, grab sampling, grain size analysis, oceanographic sampling, trawl sampling, trap sampling).
- Multibeam products should include a digital terrain model and backscatter classification (supervised eCognition procedures to classify habitats) based on ground truth and classification of grain-size and texture categories.
- Grab, video, trawl, and trap sampling stations should be identified by and inclusive of the range of habitat types, habitat patch sizes, transition zones between habitat types, and habitat distribution within the landscape of the project areas.
- All sampling should incorporate navigation systems to maximize precision of geographic location of samples (i.e. GPS of ship with offsets for sheave location for grab sampling, offsets and wire length and angle for towed systems, USBL and integrated navigation for maneuverable platforms like ROVs). This is critical for matching samples to multibeam habitat map attributes.
- It is critical to employ habitat and biological sampling methods that will be replicable once wind turbines are in place.
- Seasonal sampling (spring, summer, fall, and winter) is recommended for initial assessment of the ecological processes extant in the project areas, including transient habitat characteristics (oceanographic conditions, productivity, etc.). If seasonal sampling is not possible, a minimum of spring and fall sampling should be conducted.

Ongoing Monitoring Protocols:

In terms of ongoing monitoring protocols for assessing habitat change impacts, the following points were offered:

- All of the approaches identified above should continue during construction and operation, with the following added components:
    - Additional survey stations that encompass elements of the disturbed natural landscape and structural components of the energy installations (e.g. disturbed trenches for cables, buffer zones around structures that will be disturbed by

alteration in flow and halo effects of animals, anchor surfaces, platform legs, etc.). Particular attention should be paid to inclusion of horizontal and vertical surfaces across the depth range of structures.
    - Underwater video and sonar surveys will be particularly important to continue in areas of deep water, strong currents, and major seafloor alterations.
- Analysis of habitat monitoring data from construction and operational phases of offshore wind energy development should focus particularly on assessing the severity and frequency of sedimentation and scouring around turbines and the exposure of transmission cables, as such changes are likely to have major effects on fisheries resources.
- Ongoing monitoring efforts should also aim to assess the recovery time of different habitat types from disturbances associated with offshore wind energy development. This will require repeated sampling/surveying of fixed locations (as selected by pre-baseline studies and monitored during baseline research).
- Ongoing monitoring efforts should also aim to assess whether foundations of turbines act as artificial reefs in attracting fish or hosting invasive species.
- The biological effects of long-term habitat alteration from offshore wind energy development operation will likely be more severe than the short-term effects from turbine and cable installation. Most fish are adapted to withstand strong, short-term episodic perturbations, such as storms, but not the extended disturbances associated with offshore wind energy development operation. Thus, habitat and biological sampling should be conducted five and ten years after offshore wind energy facility construction to assess long-term changes in benthic habitat and ecosystem structure.

2.8.7 Oceanographic Conditions:

Research Needs:
Many project participants provided input on the possible impacts connected with changes in oceanographic conditions, and felt it is essential to consider how structures that rise above the seafloor and ocean surface will alter flow fields, stratification conditions, and water column structure as they influence the direct and indirect interactions between resource species as well as productivity cycles. For example, the distribution of flow refuges on the down-current side of offshore wind energy structures will likely influence the distribution of small pelagic species (i.e. squid, butterfish, herring) and their functional role as principal prey of higher trophic level predators. Thus, how tidal flow variability mediates distribution of small pelagics, based on size class variation and physiologic limits, will have direct and indirect effects on predator distributions and potentially foraging success. Furthermore, behavioral interactions between pelagic predators and prey over the seafloor can influence the distribution and predator-prey interactions of demersal piscivores (i.e. pelagic predators driving prey to the seafloor, facilitating predation by demersal piscivores). For these reasons, respondents suggested that it is critical to understand the oceanographic conditions within WEAs prior to and throughout offshore wind energy development so as to predict and mitigate negative impacts to fisheries resources species.

Baseline Research Protocols:
- Standard oceanographic monitoring techniques, including fixed seafloor and surface moorings, transient water column profiles (via CTD), and Acoustic Doppler Current

Profilers (ADCPs), should be employed to assess the oceanographic conditions and flow fields in and around the proposed offshore wind energy sites for at least three years prior to construction.

- All oceanographic sampling should be conducted year round to assess seasonal transitions and interannual variability.
- Oceanographic parameters measured by moorings and CTDs should include, at a minimum, temperature, salinity, and dissolved oxygen, plus turbidity and chlorophyll a fluorescence (a measure of primary productivity), if practicable.
- The number and placement of moorings and ADCPs will depend on the size and shape of the wind energy areas' footprints, but such platforms should be developed both within and outside the proposed wind energy areas.
- In addition to fixed oceanographic sampling via moorings, water column profiles should be conducted within each lease block every month.
- Dynamic modeling of reduced wind shear effects (as is likely to occur within wind energy areas) on stratification and flow should also be conducted prior to construction.
- Trawl, trap, and passive acoustic surveys should be used to study association and re-distribution of fish and invertebrates in relation to existing flow fields and oceanographic conditions.
- Fixed atmospheric and oceanographic monitoring stations (moorings and automated profilers) should be developed within each WEA to assess annual cycles in environmental conditions prior to offshore wind energy development.

Ongoing Monitoring Protocols:

- All in-situ oceanographic monitoring approaches should continue throughout the construction and operation phases of offshore wind energy development to assess changes in environmental conditions.
- The fixed nature of oceanographic monitoring platforms (moorings, ADCPs) should make ongoing monitoring efforts relatively low effort and cost.
- Computer models should be updated with real-time data about flow fields and oceanographic conditions within and around wind energy areas and be used to predict long term impacts of offshore wind energy development on local and regional conditions.

2.8.8 Noise & Vibration:

Research Needs:

The input received included many comments related to the observation that an increase in noise and vibration levels from pile driving will likely negatively impact many species, including larval and adult stages of commercially and ecologically important fish and invertebrates. Commenters pointed to the need to assess whether the construction and operation of offshore wind energy facilities will increase the ambient acoustics in the region significantly enough to impact species distributions and movements. It was suggested that early life stages are likely to be most severely impacted by increased noise and vibration levels, given their sensitive nature and inability to move away from the sources. Animals that use acoustics for navigation or foraging, including many teleost fishes, are also likely to be affected by the noises associated with construction and operation.

Background Research Protocols:
Generally speaking, respondents stated that the extent, attenuation, and ecological effects of noise and vibration pollution resulting from offshore wind energy development should be investigated using a combination of computer modelling, laboratory experiments and in-situ studies prior to construction. More specifically it was suggested that:

- Computer simulations should be used to model the expected acoustic attenuation of construction and operation noises for each proposed offshore wind energy facility prior to construction.
- Controlled laboratory studies should be used to assess potential impacts of noise and vibration on specific species and life stages. Particular emphasis should be placed on assessing the effects of noise pollution and vibration on the larval stages of fish and invertebrate species known to inhabit the Cox's Ledge and Cholera Bank WEAs (sea scallop, lobster, flounders, and skates).
- Soundscape assessments of WEAs should use passive acoustic recorders to measure background acoustic conditions in the absence of wind turbine construction and operation.
- Coincident ichthyoplankton and trawl/trap surveys should be conducted within and around each WEA prior to construction to evaluate the spatiotemporal distributions of fish and invertebrate larvae and adults in the absence of noise and vibration pollution.

Ongoing Monitoring Protocols:

- All of the above protocols should be continued through the construction and operation phases of offshore wind energy development to assess the extent and impacts of noise and vibration pollution within and around these WEAs.
- In addition, passive acoustics should be used to monitor the extent and attention of noise resulting from construction and operation of offshore wind energy facilities and its effects on the background biological soundscape.
- Passive acoustic surveys should also be used to assess soniferous fish activity.
- Trawl, trap, and active acoustics (side-scan, DIDSON) surveys should be used to assess the coincident spatiotemporal distribution of adult fish and invertebrates and their relationship to noise and vibration pollution.
- Ichthyoplankton surveys should also be conducted during construction and operation to assess changes in the spatiotemporal distribution of fish and invertebrate larvae in the presence of increased noise and vibration.

2.8.9 Electromagnetic Fields:

Research Needs:
The presence of electromagnetic fields produced by the transmission cables linking offshore wind energy fields and shore-side facilities was noted by many participants as a possible factor that could influence the distribution and behavior of many fish and invertebrate species. A number of EMF-sensitive species, such as lobsters and elasmobranchs, are known to migrate through as well as reside within the Cox's Ledge and Cholera Bank WEAs. Given the depleted status of the Southern New England lobster stock and the ecological significance of elasmobranch species, many felt it is essential to understand how the movement, foraging

behavior, and general distribution of these species may be impacted by the EMFs associated with offshore wind energy facilities. Both lobsters and elasmobranchs are able to sense electromagnetic fields, but their reactions to the EMFs produced by offshore wind energy facilities has yet to be determined. Possible responses include moving away from EMF sources, aggregating near EMF sources, or attacking EMF sources. There is also a possibility, however, that lobsters, skates, and sharks do not change their behavior around EMFs. Awareness of these species' reactions to EMFs prior to offshore wind energy development will help to mitigate impacts to important fisheries resources species by identifying wind energy area designs (i.e. size/configurations) to avoid interfering with migration, foraging, and reproduction.

Background Research Protocols:
In assessing potential impacts associated with the presence of electromagnetic fields, both laboratory and field baseline research methods options were identified. They included:

- A combination of controlled laboratory experiments and in-situ research should be conducted prior to offshore wind energy facility construction to assess the potential impacts to EMF-sensitive species.
- Controlled laboratory experiments are needed to determine whether species can detect the EMFs produced by offshore wind energy facilities and whether their activity is altered by such electromagnetic fields. To do this, behavioral assays with Helmholtz coils should be used. These methods have been shown to be effective with spiny lobsters.
- It would also be useful to track lobster and elasmobranch movement in mesocosms to provide perspective on how these species behave around EMFs in a near-natural habitat, which can still be manipulated to alter EMF strength, cable depth, and other factors.
- In addition to laboratory experiments, seasonal field studies should be conducted for at least five years prior to construction to assess lobster and elasmobranch abundance and distribution within proposed wind energy areas.
- For lobster surveys, the Southern New England Cooperative Ventless Trap Survey (URI), which collects biological lobster and bycatch data and bottom water temperatures from each lease block in the Cox's Ledge WEA, should be used as a guide, including the involvement of commercial lobstermen in planning and execution.
- For elasmobranchs, baseline surveys should employ techniques that are replicable after turbines are constructed, such as beam trawls and gill nets.
- In addition, acoustic telemetry should be used to study the in-situ movements of elasmobranchs and lobster, particularly if receiver arrays are already set up.
- Initial field studies should also involve sampling in areas near existing power lines and structures, if possible.

Ongoing Monitoring Protocols:

- All field components detailed above should be continued through the construction and operation of offshore wind energy facilities to assess how EMFs impact elasmobranch and lobster distribution and behavior.
- Acoustic telemetry is a particularly useful tool for assessing the in-situ response of elasmobranchs and lobsters to the electromagnetic fields produced by buried cables, as movements of tagged individuals are continuously logged by receiver arrays.

- Targeted lobster and elasmobranch surveys should also continue throughout construction and operation to assess the impacts of the installations and operation of cables (and, therefore, EMFs) on these species.
- Ideally, surveys would run continuously pre-construction, through construction, and post-construction in order to follow a Before-After Control-Impact design.

Overall, a suite of coordinated research studies, as described above, should be developed to:

- *Elucidate the seasonal use of WEAs by fish and invertebrate species and understand the environmental conditions driving these use patterns, including benthic habitat and oceanographic conditions*
- *Better understand the ecological effects of noise/vibration and EMFs on elasmobranchs and lobsters*
- *These research studies will be needed to fully assess, predict, and mitigate the impacts of offshore wind energy development on fisheries resources in the Northeast U.S.*
- *It is critical that these baseline research begin at least three years prior to development and continue, using the same methodologies, during construction and operation*
- *In order for such research programs to come to fruition, it will be essential for managing agencies, namely BOEM, to provide developers with details on baseline research and ongoing monitoring requirements*

2.9 Suggested Research Approaches

A variety of input was received which focused on the research approach itself. Over the course of discussions and through written responses, some project participants offered suggestions regarding how the needed data collection and research should be funded, how a coordinated, comprehensive baseline survey and monitoring program should be administered, and how resultant data should be shared and analyzed. The following section summarizes these suggestions. Foremost, respondents agreed offshore wind energy developers (or the offshore wind energy developers and BOEM) should be responsible for paying for (through direct payments or taxation) the needed research, especially the site specific data that is critical to making informed planning decisions and directing long term monitoring. Some respondents warned that there could be a tendency to do the least amount of data collection to save time and money but that should not be allowed to happen. In an effort to make sure the research needed is done right, it was suggested that BOEM be specific and thorough in what research they require developers to carry out, and costs should not be the controlling factor in what research gets done.

Developers should not be allowed to pick and choose research approaches and projects, but rather, should be required to fund holistic research programs that are scientifically sound with comparable results between WEAs. For each WEA, specific research topics and questions should be identified and prioritized. Prior to federal offshore wind energy development, BOEM should develop and disseminate an outline of a standard research program that is required for all WEAs. This is the only means to be able to compare and apply the results and lessons from different WEAs, and thus, is an essential component in the sustainable development of future offshore wind energy.

At the same time, it was recognized that given the long list of species present in these WEAs, the research plan which is developed needs to be feasible in terms of what can be reasonably accomplished. In other words there will not be enough time and funding to be able to do everything that could be done. It was suggested that priority be given to assessing impacts on species that are considered commercially and/or ecologically important, and any species considered endangered. Research questions should be clearly identified to avoid just monitoring for monitoring sake.

Data management was a major area of concern, and many research approach suggestions centered on the need to have data publically shared to provide transparency and the ability of outside analysis. One specific suggestion called for compiling all existing and future WEA site data into a standard format that is shared on a website operated by BOEM. Others called for requiring research related project results to be published in accessible, peer reviewed journals with the data made available online. It was felt that sharing this information would help future offshore development projects. In addition to peer reviewed publications, some suggested inclusion of project results in popular literature, trade (e.g. commercial fishing) and hobby (recreational fishing) magazines, social media, and spot media. There could also be a steering committee formed that could be involved in writing reviews about certain topics.

Other specific data management suggestions included having the data included as part of National Environmental Policy Act (NEPA) assessments ensuring that it would be reviewed and shared through the process. At the very least, standard data formats should be developed beforehand to enable direct dissemination of project databases via online outlets, and should be developed in consultation with other federal agencies, such as NMFS, to ensure consistency.

One theme which appeared to be consistent across all groups of respondents was the idea of collaboration. There was a general sense that BOEM will need assistance in developing research requirements and giving appropriate guidance to offshore wind energy developers. Respondents stressed that this assistance should come from members of the commercial fishing industry, as well as fisheries managers and scientists in the region. Some pointed out that existing BOEM Task Forces are currently underutilized because they meet too infrequently to have a real role, and members of the commercial fishing industry and academic scientists do not have direct representation in such groups. It was suggested that this needs to be corrected, and representatives of the commercial fishing industry and private/academic research institutions need to become contributing members of Task Forces.

Some respondents felt strongly that building a credible approach to fisheries resources impact assessment must involve members of the commercial fishing industry early on, and in a meaningful way that utilizes their input in deciding what research and data collection is to be a priority. They also have a role to play in terms of the implementation of the research plan, by having their fishing vessels involved. Respondents pointed out that this builds credibility and trust, along with it being cost effective. This would assure fishermen that the survey procedures will be carried out appropriately and cost effectively. Some suggested it would be particularly important for fisheries scientists and managers to work with fishermen to determine where control sites should be located for each WEA. For example, fishermen consulted as part of this project suggested that the area southwest of Noman’s Land Island has similar ecological conditions as the Cox's Ledge WEA. Scientific expertise will be required to determine whether this areas is sufficiently far enough away from the development area to act as a control site, and it will be critical for BOEM to limit additional development activities within a certain radius of control sites to preserve their un-impacted status.

Collaboration could be accomplished through the establishment of a type of Steering Committee that included representatives of all interested parties including state/regional/federal management agencies, fisheries scientists from academic and private research institutions, wind energy developers, NMFS NEFSC and GARFO, regional fishery management councils, and members of the fishing community. Some respondents also suggested that fishing fleets in these areas do their own monitoring in the form or pre and post construction conditions. Others pointed out that it would be useful to set up a system to systematically record the observations of fishermen throughout the offshore wind energy development process to provide a fishery-dependent viewpoint to ecosystem impacts.

Some of the input received focused on the leadership and administrative support that would be needed to develop and implement a comprehensive (baseline survey and monitoring) research plan. One organization (external to BOEM) could be contracted to oversee and administer site specific research programs. Some suggested that the regional fisheries management councils could play this role, following a procedure such as has been used in Research Set Aside (RSA) Programs.[17] Others though pointed out that while the Councils should be involved, they do not have the time to devote to leading the research effort, given the overwhelming management responsibilities they already have, and there were concerns about how previous RSA Programs have been run.

Some of the miscellaneous comments received under this topic included the following:

- The Northeast U.S. appears to be the first region in the country to develop offshore wind energy facilities, making it critical to focus on doing it the right way.
- Pre-baseline studies and planning for baseline and ongoing monitoring should begin prior to offshore wind facilities being designed, as it is critically important to begin accumulating appropriate baseline data as soon as possible, particularly for the Cox's Ledge WEA and WEA Southwest of Nantucket Shoals which has already been leased for development.
- The input received during this particular project should be used to lay the groundwork for future fisheries resources and economic studies of these WEAs.
- There is some concern about BOEM assuming full responsibility for the needed research because of a perceived lack of coordination between government agencies.
- There may be other types of development in these WEAs (aggregate mining, oil drilling, gas drilling) that could have other types of impacts on fisheries resources, or there could be cumulative effects from several offshore wind energy developments along the east coast. This needs to be looked at comprehensively.
- Potential negative impacts on fisheries resources in these WEAs should be thought of in terms of risks to the region’s food security.

In summary, the major concepts highlighted in the input received regarding the approaches that should be taken to assess impacts on fisheries resources included the following:

- *The data and research needed to assess impacts on fisheries resources in and around WEAs should be funded by offshore wind energy developers or offshore wind energy developers and BOEM*
- *Species of interest should be prioritized with high priority being given to species that are commercially and/or ecologically important, or protected, threatened, or endangered*
- *Data management procedures need to ensure that all resultant data is made publicly accessible and available for outside analysis*
- *The identification of research needs and the setting of priorities, together with the implementation of a comprehensive research plan, needs to be approached collaboratively by involving members of the commercial fishing industry, fisheries scientists and managers in the region, and offshore wind energy developers*
- *Pre-baseline studies and planning for baseline survey work and monitoring should begin now, with actual baseline surveys beginning as soon as possible in the Cox's Ledge WEA*
- *Leadership to facilitate the development of a comprehensive, coordinated research approach, and to organize and administes a research plan, is needed*

3.0 BACKGROUND RESEARCH

As part of the process of soliciting and gathering input on potential impacts to fisheries resources and suggested research protocols, a review of pertinent background reports and peer reviewed literature was conducted and summarized. This included background information from the European experience with offshore wind energy development as well as any specific information that could be obtained pertaining to these three WEAs here in southern New England and the New York Bight. The content of this background information follows a similar range of specificity to the participant input. Some background information was general in nature, covering groups of species and all or several of the various stages of offshore wind energy development components while other references were more specific. These addressed possible impacts on a specific species or likely affects from one particular type of development activity or structure (e.g. electromagnetic fields from cables, scouring at the base of turbines, etc.). The background information uncovered served to help inform the discussions and written response questions used in the solicitation of input from project participants as well as confirm the types of potential impacts responders mentioned. A summary of the methodology used to research background information and its findings is presented below.

3.1 Methodology:

A thorough search of existing documents was conducted to find background information relevant to potential fisheries resources impacts of offshore wind energy development in the Northeast United States and recommended approaches to assess the predicted impacts. Searches through scientific journals were conducted using the University of Rhode Island's online database system using words and phrases such as "offshore wind", "wind energy", "environmental impact", "fisheries", "ecology", etc. Literature cited was examined and in turn used to find further documents with relevant information. Environmental impact statements as well as construction and operation plans of existing offshore wind energy developments were reviewed, most of which were from European wind energy facilities. Documents and other sources of information were also discovered through review of written responses and meetings with project participants.

3.2 General Impacts:

Generally, background research findings showed that due to the lack of research conducted in the Northeast United States regarding offshore wind energy development impacts on fisheries resources, it is largely unknown how present species will react to offshore wind energy facilities. Impacts may be cumulative in time, location, and the number of offshore wind energy developments in an area, thus it will be important to consider potential impacts to the entire marine ecosystem rather than just focusing on impacts of each wind energy area independently (Inger et al., 2009). The construction phase of development is expected to have the greatest impact on fisheries resources, largely due to pile driving for turbine foundations and cable installation activities (Bailey et al., 2014).

Each species may be impacted in different ways due to differences in their physiology and behavior. Each life history stage for species may also be impacted in different ways. For example, the eggs of a species may be vulnerable to cable installation but adults may be unaffected (McCann, 2012). However, it is predicted that less mobile species (shellfish) and early life history stages (eggs and larvae) will be more vulnerable to the likely effects of offshore wind energy development due to their lack of ability to actively leave an area being impacted (McCann, 2012). It is not known if species present in these wind energy areas will be able to acclimate to the effects of offshore wind energy facilities. For example, they may exhibit initial avoidance behaviors around turbines but eventually become accustomed to them and aggregate around the structures (McCann, 2012).

The factors potentially impacting fisheries resources might act individually or they might compile to cause cumulative impacts resulting in mortality, injury, stress, behavior changes, increased energetic costs, avoidance, displacement, aggregation, habitat alteration, and/or community changes (McCann, 2012). These wind energy areas contain critical habitat used by various species for feeding, migration, spawning, or nurseries. Rodmell and Johnson (2005) suggest that the ecological impact to fisheries, both positive and negative, could occur at the population level. (Rodmell and Johnson, 2005).

3.2.1 Noise & Vibration:

Noise and vibration will result from pile driving during construction and normal operation of turbines. The noise and vibration during pile driving is expected to be more severe than operational noise and vibration (McCann, 2012). Some species present in these wind energy areas can detect pile driving up to 80 kilometers away from the source, consequently pile driving is expected to be a major factor having a potential to cause impacts on fisheries resources across large areas (McCann, 2012). Previous studies from the San Francisco-Bay Bridge Demonstration Project found direct mortality zones of marine species within 10-12 m from piling and assumed delayed mortality zones extending up to 1000 meters from pile driving (OSPAR Commission, 2008), and not-fatal impacts such as avoidance behaviors extending up to 40 miles from construction activities (McCann, 2012). Worsening effects will likely be seen with decreasing distance to the pile driving source and increasing exposure time (OSPAR Commission, 2008).

Background information indicated there are multiple ways in which species may be impacted by construction activities through primary, secondary, and tertiary effects. Primary effects include immediate or delayed fatal injuries, which is often caused by barotrauma through ruptured swim bladders in fishes. Secondary effects include non-fatal injuries that may impact an individual's future survival such as hearing damage. Tertiary effects will likely be less severe but seen over a large area; they include things such as stress, pain, discomfort, and avoidance (OSPAR Commission, 2008).

Impacts on species from noise and vibration vary in that they may be immediate or delayed, temporary or permanent, fatal or non-fatal, external or internal, auditory or non-auditory, and behavioral or physiological. Injuries that may result from noise and vibration include mortality, hearing loss, ruptured swim bladder, internal bleeding, capillary rupture, neurotrauma, hemorrhaging, liver damage, kidney damage, sensory hair cell damage, lateral line system damage, and impaired larval growth (McCann, 2012; OSPAR Commission, 2008; Hastings and Popper, 2005). Impacts that may affect behavior include communication or orientation masking and avoidance (McCann, 2012; Inger et al., 2009). These changes in behavior due to noise and vibration could cause major negative impacts to feeding, spawning, migration, and energy consumption because these wind energy areas overlap with critical habitat for many species (Bailey et al., 2014; Hawkins and Popper, 2014).

Many factors determine the degree to which an organism is affected by pile driving activities including species, organism size, presence of a swim bladder, physical condition of the organism, peak sound pressure and frequency, shape of the sound wave, pile size and material, depth of the water, depth of the organism in the water column, amount of air in the water, size and number of waves on the water surface, substrate composition, bottom topography, tidal currents, and presence of predators (NEFMC, 2014; ASMFC, 2012).

The physiology of species is one of the most important factors in determining how an individual may be impacted from noise and vibration. Studies have shown there is typically more injury to species with swim bladders than to species which do not have air chambers, such as flatfish and shellfish (Hastings and Popper, 2005). Species with swim bladders have physiological differences which may result in varying impacts from pile driving. Species with physostomous and physoclistous swim bladders may show different injuries as a result to pile driving (Popper et al., 2012).

In assessing potential impacts from increased noise and vibration levels, it is important to recognize that there are three basic categories of fishes based on their auditory sensory systems, and each category could potentially be affected differently by noise and vibration pollution. One category is composed of species without a swim bladder which can only detect kinetic energy which includes sharks, flounders, some tunas and some mackerels. Another category consists of fishes with a swim bladder located far away from the ear which typically does not contribute to pressure reception, this category includes salmonid species. The last category is composed of fishes with a swim bladder or air chamber located close to the ear which enables sound pressure detection and a broad hearing range with increased sound sensitivity. Herring and cod are included in this category (Hastings and Popper, 2005). Hearing specialists with specialized anatomical structures to detect low levels of sound pressure have also been found to experience hearing loss when exposed to increased background noise for extended periods of time, while hearing generalists without these anatomical structures do not experience hearing loss (Popper and Hastings Integrative Zoology, 2009).

3.2.2 Electromagnetic Fields:

Background research confirmed that electromagnetic fields produced by turbines and cables have the potential to impact the behavior of species in these wind energy areas. However, until specific materials and construction methods of the cables and turbines are selected, it is difficult to predict how strong the electromagnetic fields will be and how much they will affect present species.

There are different electrical cable systems that could be used in these offshore wind energy developments, with the two major systems being direct current (DC) and alternating current (AC) (Woodruff et al., 2013). AC systems produce electrical currents and magnetic fields which change direction periodically, while DC systems produce electrical currents which constantly flow in one direction (Woodruff et al., 2013). AC cable systems are employed in most offshore wind energy facilities in Europe, however wind energy developments far offshore in the United

States will likely use DC systems (Normandeau et al., 2011). AC systems typically produce magnetic fields at frequencies around 50-60 Hertz, and most marine species detect electrical signals in the range of ten Hertz or less (Normandeau et al., 2011). However, marine species may still be able to detect electromagnetic fields from cables at a range of several meters (Normandeau et al., 2011). On the other hand, DC systems have the potential to emit electromagnetic fields that could be detected by marine species at a distance of tens of meters away from cables (Normandeau et al., 2011).

Benthic species are the species most likely to interact with electromagnetic fields as the cables will run along the ocean bottom (McCann, 2012). It is predicted that elasmobranchs and other species (including sturgeon, salmon, and eels) that utilize the Earth's and other organisms' electromagnetic field for navigation and feeding will be the most vulnerable to impacts from cable-emitted electromagnetic fields, as cables may attract or repel them (Fisher and Slater, 2010). Electromagnetic fields have also been found to slow heartbeats and alter orientation, circulation, gas exchange, and development of cells in marine species (Fisher and Slater, 2010).

It has been documented in previous studies that marine species are attracted to electromagnetically charged cables. Dogfish, round stingrays, and blue sharks have been found to attack sources of electrical fields, and these species are all present in these wind energy areas (Fisher and Slater, 2010). In recent history, shark bites have also been documented on submarine optical telecommunication cables (Gill and Bartlett, 2010).

3.2.3 Artificial Reef Aggregation:

Many aspects of the fisheries resources communities within the wind energy areas are expected to be affected through habitat changes and the introduction of new structures. Offshore wind energy developments are expected to affect species abundance, density, composition, diversity, dominance, size classes, and productivity (McCann, 2012; Rodmell and Johnson, 2005).

The introduction of new structure is expected to provide new habitat for species to colonize and aggregate around, and the local communities are expected to change from non-structure based to structure based (BOEM DOE/EIS-0470, 2012). Species compositions of artificial reefs have been found to differ from natural reefs and their presence can also affect the surrounding biodiversity, thus areas outside the footprints of these wind energy areas may be impacted (Inger et al., 2009). At one offshore wind energy facility the species diversity was lower on turbines compared to nearby natural boulders, indicating the artificial reef effect of the turbines was not as beneficial as having natural rocky habitat (Wilhelmsson and Malm, 2008).

Background research did indicate there may be potential positive impacts associated with offshore wind energy development. For example, if these wind energy areas have exclusion zones surround them for navigational safety and protection of the structures, the areas may act as marine protected areas (MPA) for fisheries resources (Inger et al., 2009). MPAs can successfully increase diversity, biomass, density, and sizes of organisms within their area compared to surrounding areas (Inger et al., 2009). The net export of eggs, larvae, juveniles, and adults from MPAs into the surrounding areas is considered spillover; this spillover has the potential to bolster fisheries resources in the areas surrounding marine protected areas and protect against over-exploitation (Inger et al., 2009). The wind energy areas may also benefit benthic diversity, biomass, habitat, and biota by removing the disturbances caused by fishing gear if fishing is not allowed within the WEAs (Inger et al., 2009) (Lindeboom et al., 2011).

There are, however, potential drawbacks when looking at these wind energy areas as MPAs. If aggregation in the wind energy areas is simply a result of concentrating existing biomass around new habitat rather than increasing total recruitment and biomass, the WEAs could act as an ecological trap via increased fishing pressure and mortality (Inger et al., 2009) (NEFMC, 2014). If fishing is allowed within the wind energy areas, or even if fishing is concentrated around the perimeter of the wind energy areas to target spillover, an increase in catch could lead to errors in stock assessments which would create future problems from fishing pressure and mortality (Reubens et al., 2013).

3.2.4 Invasive Species:

Offshore wind energy development has the potential to introduce new invasive species and increase the spread of invasive species already present in the WEAs, as previous offshore wind energy developments have found invasive species colonizing turbines and their scour protection (NMFS, 2013). Non-indigenous species may find more suitable places to survive on offshore wind energy structures which may strengthen their competitive position (Degraer et al., 2013). The low structural complexity and variability of the habitat on the turbines due to their smooth surfaces could negatively affect the diversity of their colonization, and species poor assemblages on the turbines would be more vulnerable to invasion of non-native species (Wilhelmsson and Malm, 2008). Fouling assemblages in the marine environment can differ between natural and anthropogenic habitats, and anthropogenic structures can influence the communities on surrounding natural habitat (NMFS, 2013). Invasive species also have the potential to impact local communities if they outcompete native species for resources such as settlement areas and food, and this could lead to further negative impacts for species in higher trophic levels.

3.2.5 Lighting:

Turbine lighting schemes may impact the behavior of species which inhabit these wind energy areas. Artificial constant and strobe lights on turbines marking their location could cause disorientation and affect both seasonal and diurnal migrations of many species (Orr et al., 2013). Lighting may also increase predation risk and alter predator-prey interactions of species in these wind energy areas (Orr et al., 2013).

Lighting schemes also play an important role in the safety of navigation at sea for vessels that transit in close proximity to the turbines. Collision risks need to be mitigated, and vessels of all sizes need to be able to safely navigate in all weather conditions through and/or around the WEAs. Too much lighting on individual turbines or configurations with several turbines grouped together could confuse vessels trying to navigate through and around these wind energy areas (MAFMC, 2014). If a collision or accident were to occur, there is potential for chemicals and debris to pollute the WEAs and the surrounding areas.

3.3 Identification of Key Species:

As previously mentioned, to date there has been little research done on the effects of offshore wind energy development on specific species found in the Northeast United States, making it challenging to identify species to focus impact assessment efforts on. In addition, the potential for ecological impacts of offshore wind energy development make all species that are present in the region important when looking at the ecosystem as a whole. Some background information suggests that endangered species such as the Atlantic sturgeon and vulnerable species such as the basking shark should be given priority consideration due to their depleted statuses (Bailey et al., 2014).

The National Marine Fisheries Service allocates Essential Fish Habitat (EFH) to designate waters and substrate necessary to specific species for spawning, breeding, feeding, or growth to maturity. Essential Fish Habitat should be given priority consideration in planning footprints of these wind energy areas because there is EFH for many species within these WEAs (NEFMC, 2014; NMFS, 2015).

The Cox's Ledge WEA and WEA Southwest of Nantucket Shoals have 30 species with designated EFH within or in close proximity to the wind energy areas. These species include Acadian redfish, American plaice, Atlantic bluefish, Atlantic cod, Atlantic halibut, Atlantic herring, Atlantic mackerel, Atlantic salmon, Atlantic sea scallop, Atlantic wolffish, barndoor skate, butterfish, haddock, longfin squid, little skate, monkfish, ocean pout, offshore hake, pollock, red hake, shortfin squid, silver hake, smooth skate, thorny skate, white hake, windowpane flounder, winter flounder, winter skate, witch flounder, and yellowtail flounder (NEFMC, 2014; NMFS, 2015).

The Cholera Bank WEA has 24 species with designated EFH within or in close proximity to the wind energy area. These species include Atlantic bluefish, Atlantic cod, Atlantic herring, Atlantic mackerel, Atlantic sea scallop, barndoor skate, butterfish, clearnose skate, haddock, longfin squid, little skate, monkfish, ocean pout, offshore hake, pollock, red hake, shortfin squid, silver hake, white hake, windowpane flounder, winter flounder, winter skate, witch flounder, and yellowtail flounder (NEFMC, 2014; NMFS, 2015).

3.4 Species Specific Impacts:

Of the species present in these wind energy areas, some will likely be attracted to the new structures, while others will likely avoid the areas. For example, during operation some species are expected to aggregate around the turbine foundations due to increased shelter and prey; these species include black sea bass, cod, cunner, eels, octopus, pollock, sand eels, sculpin, scup, tautog, whelk, silver hake, and wolf fish (Rodmell and Johnson, 2005; BOEM DOE/EIS-0470, 2012; Leonhard and Pedersen, 2006; Polovina and Sakai, 1989; Bergstrom et al., 2013). Whelk egg masses were also found attached to turbines and the surrounding area at an existing offshore wind energy facility in Europe (Leonhard and Pedersen, 2006).

Squid and Atlantic salmon are expected to avoid the wind energy areas during all phases of development (Degraer et al., 2013; NEFMC, 2014). Studies varied greatly regarding the predicted detection ranges Atlantic salmon will have to offshore wind energy developments. One study estimated the detection range to be 400-500 meters, while another study estimated the detection range to be 25 kilometers (NEFMC, 2014; Gill et al., 2012).

There has been limited work done on the effects of pile driving on the species found in these WEAs. Herring are some of the most vulnerable species to noise and vibration in these wind energy areas, as they have wide hearing ranges and can hear pile driving up to 80 kilometers away from the source (Gotz et al., 2009; McCann, 2012). Schools of Atlantic mackerel broke apart and attempted to avoid simulated pile driving, and responded with more extreme behaviors as sound levels increased (Hawkins and Popper, 2014). Whiting exhibited initial avoidance behavior to simulated pile driving, but became habituated after an hour of intermittent firing (Rodmell and Johnson, 2005). However, whiting have also experienced mortality 24 hours post exposure to five minutes of simulated pile driving (Hastings and Popper, 2005). Sole showed avoidance behavior with increased swimming speeds in response to simulated pile driving (Mueller-Blenkle et al., 2010). There was a correlation found in striped bass exposed to equal levels of pile driving in which increasing severity of injuries were observed as the size of the fish increased. (Popper et al., 2012).

3.4.1 Atlantic Cod & Haddock:

Of all the species that are present in these wind energy areas, Atlantic cod are one of the most studied in terms of offshore wind energy development's impacts on the species. This is partially because cod are found in European waters where offshore wind energy developments have been built. Cod were found to both avoid and aggregate around offshore wind energy sites at various stages of development. There are major potential impacts to cod in the Cox's Ledge WEA and WEA Southwest of Nantucket Shoals because there are documented cod spawning grounds around Cox's Ledge and Nantucket Shoals from late fall to early spring (NEFMC, 2014; Kovach et al., 2010). The Great South Channel to the east of these wind energy areas separates this subpopulation of cod from other populations in Southern New England and the Gulf of Maine (Kovach et al., 2010).

Just as with Atlantic salmon, studies varied on the predicted detection range cod will have to pile driving. During pre-construction turbine siting cod decreased in abundance around air gun activity, and cod have shown behavioral responses to simulated pile driving (McCann, 2012; Bailey et al., 2014). One theoretical study estimated cod can hear pile driving up to 80 kilometers away from the source, another estimated they exhibit avoidance behaviors around pile driving up to 18 nautical miles (33.3 kilometers) away from the source, and another estimated they avoid pile driving at a distance of 5.5 kilometers (McCann, 2012; Rodmell and Johnson, 2005). In response to air gun and seismic shooting which results in sounds similar to pile driving, catch rates of cod and haddock decreased by 70% within one nautical mile of the source and 50% within 40 miles of the source (McCann, 2012). Cod have been delayed in reaching spawning grounds as a result of behavior changes due to pile driving; they exhibited freezing, avoidance, and higher swimming speeds (Hawkins and Popper, 2014; Mueller-Blenkle et al., 2010). A physiological result of cod exposed to simulated pile driving was the loss and damage of ciliary bundles in sensory cells (Hastings and Popper, 2005).

During operation, cod have been found to aggregate around turbine foundations and avoid cables. Cod were found to aggregate around a single turbine for up to nine months at a European wind farm, and the highest population densities of cod were found in summer and autumn when they are actively feeding (Lindeboom et al., 2011; Reubens et al., 2013). Catches of cod decreased around charged cables in Denmark, however when cables were not energized cod catches increased around the same cables (McCann, 2012).

3.4.2 Lobster:

Background research indicates the two most recent lobster stock assessments concluded that the Southern New England lobster stock is in poor condition based on established biological reference points, and further negative impacts on the stock could have major implications (RI DEM). Lobster catches were found to be unaffected by electromagnetic cables, however, lobster migrations between offshore and inshore habitats could be impacted if cables are not buried to sufficient depths or if dredging for cables creates a trench (McCann, 2012; NEFMC, 2014).

3.4.3 Flounder:

Previous studies indicate that flounder are vulnerable to offshore wind energy development due to potential changes in the benthic habitats they utilize. For example, flounder species were some of the only species to show correlations between the strength of electromagnetic fields from cables and increasing avoidance behaviors around cables, as their catches decreased around charged cables in Denmark (BOEM DOE/EIS-0470, 2012; McCann, 2012). Due to the vulnerability of winter flounder in Southern New England, jet plowing during construction activities will be avoided annually from January 1 to May 31 at the Cape Wind project to reduce impacts on the species (BOEM DOE/EIS-0470, 2012).

3.4.4 Eels:

Eel species have been studied in European offshore wind energy facilities. One study found that swimming speeds decreased as individuals passed over charged cables, but they eventually passed over the cables and migrations were not impacted (McCann, 2012). In another study, catches of eels in a Swedish wind farm decreased by 22% after construction when wind speeds were ten to fifteen meters per second, and it was determined there was an impact on migration (Rodmell and Johnson, 2005).

3.4.5 Mussels & Barnacles:

Mussels and barnacles are predicted to be the primary opportunistic colonizers on new structures associated with offshore wind energy development because they have been the principal colonizers of turbine foundations in many European offshore wind energy facilities (Leonhard and Pedersen, 2006; Joschko et al., 2008). On the foundations at a European offshore wind energy facility barnacles dominated the first three meters below the surface, then blue mussels dominated from three meters to the ocean bottom (Andersson and Ohman, 2010). Mussels also dominated turbine foundations from the surface to a depth of ten meters at a Dutch wind farm, and then tube worms and anemones dominated below ten meters (Lindeboom et al., 2011). At a wind farm in the Baltic Sea, the benthic community went from 75% blue mussel dominated to 99% blue mussel dominated over a three year period after construction, and this shift resulted in altered local ecosystem dynamics (NEFMC, 2014). Larger mussels may not be able to stay attached to turbines due to the smooth surfaces of the piles; the large mussels may eventually fall off and accumulate on the seabed surrounding individual turbines which could increase their local abundance in these WEAs (Andersson and Ohman, 2010).

3.5 Critical Locations:

Large portions of these wind energy areas were classified by The Nature Conservancy as above average in terms of species persistence and diversity, and some portions of the Cox's Ledge WEA and WEA Southwest of Nantucket Shoals were classified as far above average for both categories (The Nature Conservancy, 2014). Sea scallops also had high and very high persistence scores for large portions of these three WEAs (The Nature Conservancy, 2014).

3.5.1 Cox's Ledge:

Cox's Ledge is known to be an ecologically and historically important habitat for many fish and invertebrate species in Southern New England, with notable abundances of sea scallops and lobster (The Nature Conservancy, 2015). The Rhode Island Ocean Spatial Area Management Plan identified Cox's Ledge as having the highest ecological value of anywhere in the 1,467 square mile study area (The Nature Conservancy, 2015). The Nature Conservancy's mapping and weighted persistence analysis over three decades found Cox's Ledge to be above average and far above average for fish species and very high for sea scallops in terms of species persistence and diversity (The Nature Conservancy, 2015).

3.6 Ecological Impacts:

The structures created in offshore wind energy developments are predicted to directly increase habitat and indirectly increase food for benthic species (McCann, 2012). A Dutch wind farm saw food for fish increase by a factor of 50 around turbines compared to the previous sandy bottom (McCann, 2012). The availability of low trophic prey species on and around turbines has the capability to significantly alter the dynamics and increase the abundance of higher trophic species in the WEAs (Inger et al., 2009). However, at some European offshore wind energy facilities weak or no aggregation of reef associated prey species indicated top-down trophic control near turbine foundations (Bergstrom et al., 2013). Visual data from the North Hoyle Wind Farm in the United Kingdom found *Gadidae* species feeding on colonized fauna attached to turbine foundations (McCann, 2012).

Degradation to natural habitat through construction and decommissioning activities is another predicted impact. It could take up to ten years for communities to fully reestablish after these likely disturbances (BOEM DOE/EIS-0470, 2012).

3.7 Environmental Impacts:

There are several potential effects of offshore wind energy development which could directly impact the environment around the turbines, including the habitat and water quality, which may then have secondary effects on fisheries resources in these wind energy areas. The friction and electrical currents that will be transmitted through turbine foundations and cables have the potential to radiate heat into the surrounding water and sediment which could impact production in the wind energy areas (BOEM DOE/EIS-0470, 2012). Sediments at the Nysted Wind Farm in Denmark showed temperature increases around the power cables (OSPAR Commission, 2008).

Anchoring vessels during construction activities have the potential to damage hard bottom and other vulnerable habitats (NMFS, 2013). Gravel substrates are a limiting resource for early life stages of cod and haddock in these wind energy areas, so if those habitat areas are negatively impacted there could be resultant negative impacts on their recruitment (Greene et al., 2010). Pile driving for monopile foundations may affect large areas throughout the water column, however pad and gravity based foundations would affect larger areas of bottom habitat (ASMFC, 2012). Dredging and pile driving also has the potential to suspend pollutants that are contained in sediment (McCann, 2012).

The placement of these wind energy areas in close proximity to shipping lanes and areas of high fishing activity create a risk for navigation at sea and potential for accidents or spills. Aside from the potential for accidents and spills that could impact fisheries resources through pollution and damage to habitat, it is also expected that the increased vessel traffic required for offshore wind energy development activities could cause mobile species to avoid the wind energy areas (BOEM DOE/EIS-0470, 2012).

3.7.1 Scouring & Sediment Transport:

There is a great risk for scouring and sediment transport in these wind energy areas, as these impacts have been seen at many European offshore wind energy facilities. Sedimentation from cable dredging and other construction activities, as well as water flow around foundations during operation, can suspend and transport sediment in the water column over large areas around turbines and cable routes (Rodmell and Johnson, 2005). Wind farms in the United Kingdom experienced turbid wakes 30 to 150 meters wide and over ten kilometers long in line with tidal currents originating from individual turbines (Vanhellemont and Ruddick, 2014). Sand and other soft bottom types naturally shift over time, which creates further risk of cables becoming unburied (MAFMC, 2014).

Scour pits occurred at the Horns Rev 1 Offshore Wind Farm up to 1.5 meters in depth due to current and wave action, even with scour protection in place (Nielsen et al., 2014). The highest amount of scouring was seen around turbines in the shallowest water, and the most scouring correlated to the largest scour protections (Nielsen et al., 2014). Scour pits can also extend several meters from turbine foundations, and they can often attract lobster and crab species (Rodmell and Johnson, 2005). The Thorntonbank Wind Farm in Belgium saw lower grain sizes of sediment and increased organic matter around its turbine foundations (Degraer et al., 2013).

The extent to which scouring and sediment transport may occur depends on factors including foundation diameter, currents, waves, water depth, seafloor sediment, and artificial seafloor modifications such as scour protection (Vanhellemont and Ruddick, 2014). Through comparison of European offshore wind energy facilities it was found that seabed with unconstrained depths of sand resulted in deeper scour than seabed composed of clay (Whitehouse et al., 2008). It is generally predicted that scour depths will be 1.3 times the diameter of the foundation pile, although the greatest scour depth seen at a European wind farm was 1.75 times the diameter of the foundation pile (Whitehouse et al., 2008). Scouring is predicted to be greatest during storm events with strong currents and storm surges (Whitehouse et al., 2008).

Long term scouring along turbine foundations and cables could result in changes to bottom habitat and bathymetry (NMFS, 2013; Vanhellemont and Ruddick, 2014). Long term sediment suspension can also have an effect on light penetration which may lead to lower photosynthesis rates and decreased production in these wind energy areas (NEFMC, 2014). Changes to light penetration may also have an effect on visual predation (Vanhellemont and Ruddick, 2014). Immobile species such as shellfish might be vulnerable to sediment transport because they may be suffocated or become buried (BOEM DOE/EIS-0470, 2012). Eggs and larvae may also be vulnerable to mortality due to burial through sediment transport; however the loss of eggs and larvae is expected to have a minimal impact on adult populations due to the general low survivability of eggs and larvae to adulthood for most marine species (BOEM DOE/EIS-0470, 2012). High turbidity can cause other adverse impacts to marine species including greater energetic costs, gill tissue damage, and mortality (NMFS, 2013).

3.7.2 Sand Ridges:

Sand ridge habitat is vulnerable to changes in currents and sediment transport. They may be considered EFH and are an important part of the inner continental shelf seascape (Vasslides and Able NJ Academy of Science, 2008). Many fish and invertebrate species use sand ridges at various life history stages (Vasslides and Able Fishery Bulletin, 2008). Sand ridges have higher species abundance and richness compared to surrounding inner continental shelf habitats, and they contain distinct species assemblages including commercially important species (Vasslides and Able Fishery Bulletin, 2008).

Mollusks and other invertebrate species utilize sand ridges for larval settlement, which in turn leads to increased pelagic fish abundance due to the high abundance of prey (Vasslides and Able Fishery Bulletin, 2008) (Viscido et al., 1997). This process can be seen up higher trophic levels, showing that sand ridges can serve as key types of structure (Vasslides and Able Fishery Bulletin, 2008). They provide important prey sources and increased foraging success for weakfish, Atlantic croaker, and American silver perch; if sand ridges in these wind energy areas are negatively impacted these species could indirectly be negatively impacted (Vasslides and Able NJ Academy of Science, 2008).

3.8 Suggested Research Protocols:

Most European offshore wind energy facilities did not follow standardized protocols for offshore wind energy development environmental impact research, with Germany being the only country to have requirements in place for environmental impact assessments (McCann, 2012). Inadequate environmental impact research can create problems when analyzing short data sets because it is difficult to differentiate between impacts caused by offshore wind energy developments versus impacts caused by natural interannual variation (McCann, 2012). Inappropriate sampling gear can also cause errors in data analyses, for example a beam trawl is not an effective method to survey for pelagic fish species (McCann, 2012).

Studies should examine things such as population sizes, sex ratios, fecundity, age structure, maturity schedules, natural mortality, fishing mortality, and growth rates (RI DEM). Survey sites should be selected randomly, but they should occur both transecting turbines and along cable lines (McCann, 2012). Some species undergo diurnal migrations, so faunal surveys should take place both during the day and at night (Leonhard and Pedersen, 2006).

Background research indicates that once protocols and equipment configurations are selected and put into use, they should remain consistent throughout all phases of research. All protocols and equipment should remain consistent from the start of baseline research to the end of monitoring to minimize sources of logistical error (Federal Maritime and Hydrographic Agency, 2013). It has also been determined that identical protocols and equipment configurations should be used in both the wind energy areas and control areas to minimize logistical variation, and all areas should be sampled within a short time frame to minimize natural variation (Federal Maritime and Hydrographic Agency, 2013).

3.8.1 Experimental Designs:

The most frequently recommended experimental design for determining the impacts of offshore wind energy development on fisheries resources is a Before-After Control-Impact system (McCann, 2012). Further recommendations also include a beyond BACI design which uses multiple control areas (McCann, 2012).

There are some drawbacks to BACI experimental designs. They are limited in their ability to characterize spatial variability; samples are assigned to either a treatment area or control area (Bailey et al., 2014). Control sites are arbitrary because they must be far enough away from the wind energy area in question to be unaffected by potential impacts, but they must be close enough to the wind energy area to have comparable environmental and ecological conditions (Bailey et al., 2014). Factors with the potential to cause impacts over large geographical areas (impacts due to sound might be seen over 80 kilometers from pile driving sources) make it difficult to choose appropriate control sites (Bailey et al., 2014). Due to this, data collection areas should be larger than the overall footprint of the wind energy areas (MAFMC, 2014). Differences in a single wind energy area's natural variability can also cause problems when statistically detecting impacts (Bailey et al., 2014).

Gradient design experiments are more sensitive to change for impacts that disperse from a point source such as sounds or contaminants (Bailey et al., 2014). Gradient experiments are also more powerful than BACI experiments in detecting changes due to disturbance and studying spatial scales of impacts such as displacement (Bailey et al., 2014). This experimental design is essentially looking for a ripple effect, as data is categorized based on its distance from the source and a control site is not used (Bailey et al., 2014).

3.8.2 Survey Methodologies:

In order to obtain appropriate amounts of data to adequately examine the impacts of offshore wind energy development on fisheries resources, several survey methods used to cover all areas of possible impacts are recommended (McCann, 2012). All survey methods have advantages and disadvantages, and when compiled together they are able to build a more complete picture regarding the effects of offshore wind energy development. The survey methods and protocols which are put in place need to have the statistical power to detect the effects which are predicted to occur, and any models used to predict effects need to be validated through field measurements and studies (Bailey et al., 2014).

Survey methods which should be conducted at offshore wind energy development sites for environmental impact monitoring include a fishing industry vessel and data analysis, swath or multibeam bathymetry, side scan sonar, acoustic tagging, underwater video and photography by divers or ROV, grab or sediment sampling with grain size and organic carbon content analysis, habitat mapping, beam trawl, benthic and pelagic otter trawl, scallop dredge, gillnet or trammel net, ventless lobster trap, ventless fish trap, hook and line, noise monitoring, biofouling community analysis, and physical oceanography monitoring at the surface and bottom of salinity, temperature, and oxygen (RI DEM; McCann, 2012; Federal Maritime and Hydrographic Agency, 2013).

Acoustic tagging studies can provide data on the abundance, distribution, and movement of mobile species that can be difficult to sample due to their association with hard bottom habitat, potentially including turbine foundations (RI DEM). Acoustic arrays could be arranged to detect migration corridors, spawning areas, or feeding areas (RI DEM). Habitat mapping would be needed to understand the relationships between species and their preferred habitat; over time it could be determined how potential habitat changes from new offshore wind energy structures and cables impact species (RI DEM).

Beam trawls and ventless trap surveys are beneficial because they can access hard bottom habitats including rocky and ledge bottoms that are difficult to sample by otter trawls (RI DEM). Supplementing trawl data with gillnet or trammel net data would also be beneficial, however these nets require daily maintenance and monitoring which might not be feasible for some portions of these wind energy areas which are far offshore (RI DEM). Fish traps would be beneficial for sampling structure dependent species that may aggregate around turbine foundations (RI DEM). There should also be ventless lobster trap surveys due to the lack of selectivity for lobster, crabs, and other invertebrates in trawl surveys (RI DEM).

3.8.3 Baseline Research:

Baseline data collection prior to construction should begin as early as possible in these WEAs to account for natural interannual variation in the environment (MAFMC, 2014). A timeline should be created which specifies what type of information will be collected during each phase of development (MAFMC, 2014). Baseline information that would be needed for these wind energy areas include the abundance, distribution, and trends of species within the potentially affected areas, including the areas surrounding the overall footprints of the WEAs (Bailey et al., 2014). It is recommended to collect at least two years of baseline data, however longer time series would be ideal to identify possible natural interannual variation versus effects caused by offshore wind energy development construction and operation (Bailey et al., 2014).

Germany requires two years of baseline data prior to construction with sampling occurring in the spring and fall (Federal Maritime and Hydrographic Agency, 2013). If construction does not begin within two years of the completion of the baseline data collection, more data is required prior to construction (Federal Maritime and Hydrographic Agency, 2013). If more than five years pass between the completion of the original two years of baseline data collection and construction, a new complete two year baseline study must be conducted (Federal Maritime and Hydrographic Agency, 2013).

3.8.4 Long Term Monitoring:

Post-construction monitoring should take place for at least a decade to monitor the long term effects of offshore wind energy development, but yearly monitoring is not necessarily required (McCann, 2012). Germany requires operational phase monitoring to take place in years one, three, and five after operation begins, while the Cape Wind project will only conduct post-construction monitoring in the two years following the completion of construction (McCann, 2012).

3.9 Suggested Research Approaches:

All stakeholders and parties interested in offshore wind energy development in these wind energy areas should be involved in all stages of design, baseline research, impact assessment monitoring, construction, operation, and decommissioning of the facilities (Inger et al., 2009). These parties should include developing energy companies, engineers, local communities, government and non-governmental organizations, fishing industries, and research institutions (Inger et al., 2009). It is essential for planners, regulators, industry members, and scientists to communicate and coordinate efforts to ensure that studies are properly designed and carried out (Bailey et al., 2014).

All research that is conducted should be transparent, data should be made publicly available, and results of studies should be published in peer reviewed scientific journals to allow researchers to conduct further experiments and ensure scientific credibility (Inger et al., 2009). All data should be catalogued in a consistent fashion to compare results over time and between sites; a comprehensive online database would aid this process and facilitate research (Whitehouse et al., 2011).

There is potential for natural or anthropogenic disturbances other than offshore wind energy development to compromise the research conducted for environmental impact assessments of these wind energy areas (Bailey et al., 2014). Any cumulative impacts caused by events outside the scope of work of offshore wind energy development construction, operation, and decommissioning need to be taken into account when analyzing results of studies (Bailey et al., 2014).

Areas of potential effect for each predicted impact need to be defined before baseline surveys begin; overestimation of the area of potential effect is better than underestimation (Bailey et al., 2014). Connections between key populations and specific wind energy areas (or portions of wind energy areas) need to be made, and the significance and scale of population level impacts need to be identified (Bailey et al., 2014). Populations which exist in these wind energy areas need to be identified and their status needs to be determined prior to baseline research (Bailey et al., 2014). There also needs to be a link between responses of individual organisms which correlates to population level consequences for the species (Bailey et al., 2014).

3.9.1 Ongoing Studies:

There are a few ongoing baseline studies funded by the Bureau of Ocean Energy Management which are examining potential impacts of offshore wind energy development on fisheries resources in the Northeast United States. These projects are some of the first to examine these potential effects on the species present in these wind energy areas.

The "Southern New England Cooperative Ventless Trap Survey" is researching the lobster resource in the Cox's Ledge WEA and WEA Southwest of Nantucket Shoals (BOEM, March 2015). This study underway by the University of Rhode Island and Rhode Island commercial fishermen established a ventless trap survey protocol to determine the seasonal and spatial patterns of lobster abundance and distribution in these two wind energy areas (BOEM, March 2015). The project includes two years of pre-development data collection for a BACI experimental design, and analyses will be conducted once data is collected during the construction and operation phases in these WEAs (BOEM, March 2015).

The University of Rhode Island is also conducting a study on "EMF (Electromagnetic Field) Impacts on Elasmobranch (sharks, rays and skates) and American Lobster Movement and Migration" (BOEM, March 2015). Goals of this project include determining electromagnetic emissions by cables of offshore wind energy facilities, responses to electromagnetic fields by lobster and elasmobranchs, and movement of lobster over electric cables (BOEM, March 2015). The study will include a mark and recapture study and field surveillance monitoring using a ROV equipped with electromagnetic measuring instruments (BOEM, March 2015).

The National Marine Fisheries Service Northeast Fisheries Science Center is conducting a study titled "Fishery Physical Habitat and Epibenthic Invertebrate Baseline Data Collection" in all wind energy areas along the east coast of the United States (BOEM, March 2015). This habitat study is assessing and characterizing the benthic habitat and epibenthic macro-invertebrate community in the wind energy areas using multibeam sonar, video and photography of the ocean bottom, along with geophysical surveys (BOEM, March 2015). This information will be utilized in turbine siting, impact assessments, and lessee habitat surveys (BOEM, March 2015).

The University of Massachusetts Dartmouth is conducting research on the "Use of Northeast Coastal Ocean Forecast System in Offshore Wind Energy Resource Planning" to determine the large scale coastal and oceanic effects of offshore wind energy developments on environmental conditions and habitat in and around the wind energy areas in the Northeast United States (BOEM, March 2015). The project is utilizing the hindcasting and forecasting capabilities of the Northeast Coastal Ocean Forecast System (NECOFS) developed by the University of Massachusetts Dartmouth Marine Ecosystem Modeling Dynamics Laboratory to develop temporal and spatial simulations of offshore wind energy development impacts on physical oceanographic conditions (BOEM, March 2015). NECOFS operates using a Finite-Volume Coastal Ocean Model (FVCOM) with variables including surface wind, air pressure, precipitation/evaporation, surface heat flux, ocean currents, water temperature and salinity, and significant wave heights and frequencies (BOEM, March 2015). With up to 30 years of hindcasting data and a potential grid size of less than one meter, these models could allow BOEM to predict the effects of individual turbines and entire offshore wind energy developments on ocean circulation and egg and larval transport, as well as predict the tracks of spills related to potential vessel collisions.

3.10 Mitigation:

Background research provided some added information regarding mitigation measures. For example, potential impacts from pile driving noise and vibration can be mitigated in various ways. Suction, gravity, pad, and floating turbine foundations do not require pile driving, but they may not be suitable for the environmental conditions which are present in these wind energy areas (Snyder and Kaiser, 2009; ASMFC, 2012). Use of vibratory hammers, drilled shafts, or press-in piling methods rather than impact pile driving methods could eliminate impact pile driving altogether if they can be used practicably (ASMFC, 2012). Noise abatement devices such as bubble curtains can reduce noise exposure to surrounding organisms, which can potentially reduce impacts including mortality, injury, and behavior changes (NMFS, 2013). Acoustic harassment devices and slow start procedures may also minimize impacts to nearby mobile organisms by encouraging them to leave pile driving areas prior to high impact activity (NMFS, 2013). Timing construction activities around vulnerable feeding, migration, spawning, and nursery areas and times of year could also mitigate impacts from pile driving (Rodmell and Johnson, 2005).

Some previous studies suggest it may be possible to mitigate the potential impacts of electromagnetic fields through various construction designs and protocols. Burying cables in the sediment on the ocean floor would create a physical barrier between the cables and benthic species, but nonmagnetic sediment is ineffective in weakening electromagnetic fields produced by electrical currents (Rodmell and Johnson, 2005). Burying cables also has the benefit of mitigating the potential for damage to the cables from fishing gear and anchors (Rodmell and Johnson, 2005). Heat radiation from cables into the water column can also be minimized by burying the cables at least six feet in the sediment (ASMFC, 2012). It is also possible to limit the strength of electromagnetic fields by having two or more parallel cables in each cable route with electrical currents running in opposite directions (Rodmell and Johnson, 2005). This bipolar system of transmission is done with forward and return conductors; European offshore wind energy facilities have used three-conductor alternate current cable systems or two-conductor bipolar direct current cable systems to offset electromagnetic fields (ASMFC, 2012). Wrapping cables with highly permeable materials or thick materials with high conductivity, such as copper, can also reduce the strength of electromagnetic fields emitted from cables (Rodmell and Johnson, 2005).

Background research findings also included reports on methods for mitigating potential environmental impacts from offshore wind energy development. For example, if these wind energy areas are located along migration routes for a species, the layout of the turbines should be parallel to the direction of migration as opposed to perpendicular to the direction of migration (ASMFC, 2012). However, this could be difficult if multiple species migrate through the same areas in different directions. Midline buoys on anchor lines can minimize impacts from anchor line sweeps; they are being used in the Cape Wind project (BOEM DOE/EIS-0470, 2012). Vessel operators should be given detailed maps of sensitive bottom habitat areas to minimize the amount of anchoring in vulnerable areas (NMFS, 2013). If possible, turbines should not be sited within 1,000 feet of hard bottom or other sensitive habitats (ASMFC, 2012).

Measures should be taken to prevent accidents and spills in these wind energy areas. For example, speed limits for all vessels should be implemented during all phases of offshore wind energy development in the wind energy areas and shipping lanes which are in close proximity to the wind energy areas (MAFMC, 2014).[18] An accident plan should be created for all offshore wind energy developments prior to construction for dealing with potential collisions and spills of debris and toxic substances (MAFMC, 2014). A plan should also be created to deal with marine debris that is discovered during offshore wind energy development activities (MAFMC, 2014).

Scouring and sediment transport could be mitigated through a variety of methods. Scour protection should be installed around turbine foundations, and it should be done during construction as a proactive approach rather than reacting to scouring that has already started (Whitehouse et al., 2011). Scour protection that was added to European offshore wind energy facilities after scouring had already begun resulted in secondary scouring that was more severe than the original scouring (Whitehouse et al., 2011). Scour protection may prevent scouring, but it can cause a larger disturbance to the natural bottom habitat than just the installation of the turbine pile (ASMFC, 2012). Hydraulic jet plowing for foundation and cable installation results in less sediment suspension and transport than traditional dredging and pile driving hammers can be used for minimal sediment disturbance.[19]

In summary, the major points derived from background research include:

- The potential impacts of offshore wind energy development on fisheries resources are generally not well understood, particularly for species in the Northeast United States
- The impacts on fisheries resources will likely vary during each phase of offshore wind energy development including construction, operation, and decommissioning, with differential impacts on larval, juvenile, and adult life history stages of resource species
- Factors which may impact fisheries species in and around wind energy areas include noise and vibration, electromagnetic fields, artificial reef aggregation, introduction of invasive species, lighting schemes, ecological changes (i.e. trophic cascades or species compositions), habitat alteration, environmental changes (i.e. scouring and sediment transport), habitat changes, chemical and debris spills, and vessel collisions or allisions, among others
- In previous studies, a minimum of two years of baseline research prior to construction was needed to detect statistically significant changes in fisheries resources as a result of offshore wind energy development
- European experiences highlight the importance of stakeholder collaboration, research transparency, and public data access

4.0 OBSERVATIONS AND CONCLUSIONS

The input and background information compiled by this project indicate that predicting, assessing, and mitigating impacts to fisheries resources from offshore wind energy development in the Northeastern United States will require coordinated and comprehensive research and monitoring programs for each proposed project. To begin, such work will need to focus on creating a baseline understanding of how individual WEAs are utilized by key species, and to some degree, how each functions at an ecosystem level. Such knowledge could assist BOEM with developing guidelines, protocols, and regulations aimed at minimizing negative impacts on fisheries resources as offshore wind energy development proceeds in the Northeast U.S. Adequate baseline research would also enable detection of environmental changes associated with each phase of offshore wind energy development, the resulting impacts on fisheries resources, and ultimately the ecological and economic significance of these impacts, all of which are key to informing future offshore development decisions.

The comments and concerns voiced by scientists, managers, and fishing industry representatives throughout the course of this project highlight the challenges of properly assessing, and possibly mitigating, impacts to fisheries resources. As offshore wind energy development projects progress, it will be critical to involve a variety of experts to determine what species should be focused on, what survey methods are most appropriate to use for baseline surveys and ongoing monitoring, how resultant data should be managed, analyzed and shared, and how the work could be approached in a collaborative way to ensure a sense of satisfaction and credibility from all involved.

The input gathered by this project also suggests that underlying research questions should be identified first and foremost and used to inform decisions regarding research needs and approaches. The following list summarizes the broad, major research questions identified by project participants, which could serve as the foundation for future research programs within proposed wind energy areas (as outlined in Section 5.0). Suggestions for specific research protocols associated with each of these research questions are provided in section 5.2. These are not in a prioritized order.

1. How do larval, juvenile, and adult life stages of fish and invertebrate species use each proposed WEA throughout the year (i.e. larval settlement, growth and reproduction, foraging, migration)? How do species change their utilization of these areas during the construction and operation of offshore wind energy facilities?
2. Are endangered fish species, such as Atlantic sturgeon, present within the WEAs at different times of year? If so, are their distributions or life histories impacted by the construction and operation of offshore wind energy facilities?
3. How do species interact with each other (competition, predation) within each WEA and how do these interactions structure seasonal fish community structure? How does offshore wind energy development impact such trophic interactions and cascades?
4. What are ecological indicator species for each WEA and how do their distributions and abundances change during and after offshore wind energy development?
5. Are there non-native species that are likely to establish themselves within the WEAs after construction (i.e. Didemnum tunicates, etc.)? If so, how would their introduction impact native species and ecosystem structure?

6. What habitats are present within each WEA and how do larval, juvenile, and adult stages of fisheries species utilize them? Do the WEAs contain Essential Fish Habitat? How do construction and operation of offshore wind energy facilities alter the distribution of habitats within each WEA?
7. How stable and resilient (i.e. disturbance recovery times) are the habitats and benthic communities within each WEA and how might offshore wind energy development alter these features?
8. What are the seasonal circulation patterns (surface and bottom) within each WEA and how might offshore wind energy development alter these patterns (both around individual pylons and the entire WEA)?
9. What are the primary productivity cycles within each WEA (benthic and pelagic production)? Does the installation of offshore wind energy facilities impact productivity regimes?
10. How do fisheries species, such as lobsters, crabs, and elasmobranchs, respond to electromagnetic fields produced by transmission cables associated with offshore wind energy facilities? Do EMFs alter migration, spawning, or foraging behaviors?
11. How are distributions and mortality rates of larval, juvenile, and adult life stages of resource species impacted by the noise and vibrations produced by the construction and operation of offshore wind energy facilities?
12. How might fisheries resources be impacted by accidents associated with offshore wind energy development such as vessel allisions/collisions, storm damage, turbine collapse, or oil/contaminant spills?

5.0 SUGGESTED BEST PRACTICE PROTOCOLS

The following section outlines suggested best practice protocols for monitoring and assessing impacts to fisheries resources from offshore wind development in the WEAs discussed during this project. These suggested best practice protocols are based on the input received from fisheries scientists, managers, and members of the commercial fishing industry, and background research conducted during the project, and are directly related to the research questions identified in the previous section of this report. It should be noted, however, that given the wide range of research suggestions received and the preliminary nature of most of the existing research, the list that follows should be considered a draft open to further discussion and evaluation by BOEM staff and others. It is intended to reflect the key elements of a research program aimed at assessing impacts of offshore wind energy development on fisheries resources, and serve as a basis for developing more detailed, yet logistically and financially reasonable research strategies for each individual WEA that are informed by preliminary site development plans.

This section is organized into three parts:

- **Part 5.1** - Suggestions regarding a process for developing and implementing a comprehensive research and monitoring program to assess fisheries resource impacts;
- **Part 5.2** - Suggested research protocols pertinent to the needs of the three WEAs in the Southern New England/New York Bight area; and
- **Part 5.3** - Preliminary suggestions for measures to mitigate possible negative impacts on fisheries resources from offshore wind energy construction and operation activities. Detailed methods to reduce negative impacts to fisheries resources, however, are difficult to identify due to the current lack of site specific information and detailed development plans for the WEAs discussed.

The suggested best practice protocols identified herein should be considered preliminary and used as a starting point for further discussions and evaluations aimed at developing detailed, comprehensive research plans for each individual WEA. It was the expectation of those who participated in this project that BOEM, as part of its charge to advance environmentally responsible offshore energy development, will take the lead in implementing these practices, and develop appropriate research and monitoring requirements for developers that will ultimately provide a sound basis for assessing impacts on fisheries resources from all phases of offshore wind development activities.

5.1. Suggested Approaches for Developing a Comprehensive Research Program:

Suggested approaches for developing and implementing a comprehensive research and monitoring program to assess the impacts of offshore wind energy development on fisheries resources include:

1. Develop an interstate Working Group for each WEA to assist BOEM with developing, prioritizing, directing, and reviewing fisheries research and monitoring efforts.
    - An interstate Working Group would be convened and led by BOEM, and not state

entities.

  - An interstate Working Group would embrace a collaborative approach and include representatives of the commercial fishing industry, state/regional/federal fisheries managers, and fisheries scientists.
  - More specifically, the Working Group would: a) provide specific guidance to BOEM for implementing a pre-baseline research plan; b) finalize and prioritize key research questions and the accompanying research/monitoring approaches specific to each WEA; c) establish a detailed work plan and schedule; d) assist with the implementation of a research program; and e) review data and research results and apply to WEA management/regulation.

2. Require offshore wind energy developers to appropriately fund the research and monitoring needed either through direct payments or taxation as part of their permit requirements. This might be supplemented by BOEM funded research activities that support the overall research program for each WEA.
   - BOEM would play the lead role in delineating the research requirements and ensuring that they are completed appropriately with the assistance of the Working Group.
3. Develop holistic research and monitoring programs for each WEA that are specific to the individual needs of each area while also maintaining consistency with standard approaches for all WEAs in the northeast region.
   - This undertaking would be led by BOEM with assistance from the Working Group for each WEA.
4. Develop research programs that are feasible and can be reasonably accomplished.
5. Include fishermen and their fishing vessels and gear in implementing the research plan for each WEA through a cooperative research approach.
6. Identify key species within each WEA to focus on based on commercial and/or ecological importance, stock status, and endangered/protected designation.
   - This would also be accomplished by the Working Group for each WEA and would be supervised by BOEM.
7. Develop a centralized and transparent data management system that utilizes standard formats and provides access to all interested parties.
   - Ensure that there is opportunity for outside analysis, and that all data analyses and conclusions are peer reviewed.
   - BOEM would be responsible for developing and overseeing this data management system.
8. Develop a central repository for all WEA reports and analyses that is easily accessible, and encourage the communication of results in a variety of formats and media outlets.
   - The BOEM website could be used as a platform for report communication.
9. Designate an outside entity knowledgeable of the interested parties and concerns in each WEA that can work in partnership with BOEM to help lead a coordinated, collaborative, comprehensive approach to developing and implementing a required research/monitoring program for each WEA.

10. Focus on accumulating the necessary baseline information in order to be able to assess changes once development begins.
    - Utilize pre-baselines studies to plan baseline work and ongoing monitoring.
    - BOEM would be responsible for implementing these pre-baseline studies, with advice from the Working Group for each WEA.
11. Consider the cumulative impacts of several WEAs in a region and devote resources to evaluating this aspect comprehensively.
12. Focus on developing an efficient and effective process for assessing impacts to fisheries resources in the northeast that can serve as a model for other regions.

5.2 Suggested Research Protocols:

In terms of research protocols to assess the impacts of offshore wind energy development on fisheries resources, the following suggestions are offered. Corresponding research questions *(RQs)*, as identified in section 4.0, are provided in *italics* after each suggested research protocol.

5.2.1 General:

1. Conduct a thorough compilation and analysis of existing data (fish and invertebrate biogeography, larval assemblages, spawning grounds, trophic structure, habitat, oceanographic conditions, soundscape, etc.) for each WEA to identify pre-baseline research needs and develop efficient sampling strategies. *(All RQs)*
    - BOEM would be responsible for conducting this task prior to the implementation a WEA-specific research programs.
2. Employ a holistic approach to baseline research and ongoing monitoring to enable the detection of unanticipated impacts from WEA development. *(All RQs)*
    - An ideal research program would incorporate the use of trawls (otter and beam trawls), fixed gear (lobster traps), acoustic telemetry, ichthyoplankton sampling, tissue/stomach sampling, visual surveys (habitat cameras), grab sampling, interferometric sonar surveys, and oceanographic observation and modeling (stratification, flow), and data collection would occur during all four seasons.
    - In addition, studies to assess the ambient soundscape, the extent of noise pollution during construction and operation, and the in-situ response of fish and invertebrate species to EMFs around transmission cables are also advisable.
    - BOEM would be responsible for requiring developers to include these components in their baseline research and ongoing monitoring programs.
3. Utilize preliminary site development plans when determining sampling station locations for baseline research and ongoing monitoring so that station relocations due to installation of infrastructure are minimized, and a reasonable and pertinent sampling strategy can be developed early on. *(All RQs)*
    - Developers should be required to share site plans with the entities planning pre-baseline research, including academic institutions, private research organizations, and state and federal agencies.

4. Designate appropriate control sites for each WEA that can function throughout all phases of offshore wind energy development. *(RQs 1-4, 6-11)*
    - Control sites should have similar environmental conditions and species compositions as the WEA and should also be far enough away from the construction site so that they will not be impacted by offshore wind energy development.
    - Scientists and fishermen should pool existing knowledge of each WEA and work together to identify control sites early in the development process.
    - This task would be accomplished by the Working Group for each WEA, developed by BOEM.

5.2.2 Pre-Baseline Research Protocols:

1. Conduct seasonal pre-baseline species assemblage surveys (trawls/traps) to assess what species are present within each WEA throughout the year. *(RQs 1-5)*
    - Use the findings from this work to determine the most effective sampling schedules, gears, and designs for extended research programs.
2. Conduct habitat surveys that are informed by site development plans prior to the initiation of baseline and ongoing monitoring research programs. *(RQs 6-7)*
    - Use this information to identify critical habitat areas and stratify and select recurring sampling stations to cover all habitat types within the planned development area.
3. Conduct statistical power analyses to determine the minimum sampling density and distribution that is needed to detect changes in species distributions, interactions and environmental conditions. *(RQs 1-9)*
    - Use the results of these analyses to refine sampling protocols for baseline research and ongoing monitoring to maximize ecological change detection capabilities.

5.2.3 Baseline Research Protocols:

1. Require a minimum of three years of baseline research prior to the construction of offshore wind energy facilities, including fish/invertebrate surveys, trophic structure analysis, habitat surveys, oceanographic monitoring, and ambient soundscape assessment to assess existing spatial and interannual variability within WEAs and to enable detection of future changes. *(RQs 1-9)*
2. Conduct baseline research throughout the year to assess seasonal patterns and identify potential mitigation techniques. *(RQs 1 & 2)*
3. Employ baseline survey approaches that are replicable during construction and operational phases of offshore wind energy development in order to facilitate comparisons that have the greatest statistical power to detect change. *(All RQs)*
4. Otter trawl surveys should not be exclusively employed for baseline surveys, as turbines and cables may prevent the use of otter trawls after construction. Use the results of baseline research to identify mitigation techniques that are applicable prior to construction, such as alternate WEA footprints, turbine anchoring techniques, or cable routes that will minimize negative impacts to fisheries resources. *(RQs 1 & 2)*

5. Employ multiple approaches to sample fish and macrofaunal invertebrates, including protected species, to ensure adequate representation of all species groups potentially affected by offshore wind energy development, including: bottom trawls, beam trawls, ventless trap surveys, hydroacoutic surveys, and acoustic telemetry. *(RQs 1-5)*
   - Develop specific gear designs (net dimensions, configuration, mesh size, trap dimensions) and sampling protocols (tow length, soak time) should be developed with input from the commercial fishing industry, and should strive to maintain consistency with ongoing regional-scale projects, such as the Virginia Institute of Marine Science's North East Area Monitoring and Assessment Program (NEAMAP) and Southern New England Cooperative Ventless Trap Survey.
   - Survey locations should be selected to provide coverage of lease blocks, representative habitat types, depths, and oceanographic conditions (as determined by pre-baseline research), while avoiding locations that will be inaccessible due to direct effects of construction.
6. Conduct ichthyoplankton surveys (bongo and manta net tows) in all lease blocks as well as a control area to assess larval assemblage and distribution throughout the year. *(RQ 1)*
7. Assess trophic interactions via carbon and nitrogen stable isotope analysis, stomach content analysis, and benthic faunal sampling (i.e. seafloor grabs). *(RQ 3)*
   - Collection of tissue and stomach samples can be incorporated into other field programs, including mobile and fixed gear surveys.
   - Sampling priority should be given to species of ecological and economic importance, while ensuring that all species groups are represented.
8. Employ a combination of acoustic telemetry and whole-fish sampling (method depends on target species) to assess the spawning activities of individual species within these WEAs. *(RQs 1-5)*
   - Reference existing studies on spawning activities and habitat preferences to narrow sampling windows.
9. Complete full-coverage interferometric sonar surveys (bathymetry and backscatter) of WEAs to assess variability of sediment structure and direct more detailed habitat and macrofaunal assemblage surveys (underwater video, grab sampling, grain size analysis, oceanographic sampling, trawl sampling, trap sampling). *(RQs 6 & 7)*
   - Grab, video, trawl, and trap sampling stations should be identified by and inclusive of the range of habitat types, habitat patch sizes, transition zones between habitat types, and habitat distribution within the landscape of the project areas.
10. Utilize fixed seafloor and surface moorings, transient water column profiles (via Conductivity, Temperature, and Depth instruments, CTDs), and Acoustic Doppler Current Profilers (ADCPs) to assess the oceanographic conditions and flow fields in and around WEAs. *(RQs 7 & 8)*
    - Temperature, salinity, dissolved oxygen, turbidity, and chlorophyll a fluorescence (a measure of primary productivity) should be measured by moorings and CTDs
    - The number and location of moorings and ADCPs will depend on the size and shape of the WEA, but such platforms should be developed both within and outside the WEA.

  - In addition to fixed oceanographic sampling via moorings, water column profiles should be conducted within each lease block every month. These can be conducted in coordination with other survey efforts, such a trawl/trap surveys.

11. Complete soundscape assessments of WEAs using passive acoustic recorders to measure ambient acoustic conditions in the absence of wind turbine construction and operation. *(RQ 11)*
12. Use computer simulations to model the expected acoustic attenuation of construction and operation noises for each proposed offshore wind energy facility prior to construction. *(RQ 11)*
13. Conduct controlled laboratory studies to assess potential impacts of noise and vibration on specific species and life stages. *(RQ 11)*
    - Focus on assessing the effects of noise pollution and vibration on the larval stages of fish and invertebrate species known to inhabit the WEAs.
14. Employ a combination of controlled laboratory experiments and field studies to assess potential impacts to EMF-sensitive species. *(RQ 10)*
    - Initial field studies should utilize existing power lines and structures to simulate the conditions of wind energy facilities.

5.2.4 Monitoring Construction and Operational Phases:

- Continue baseline research surveys and protocols through the construction and operational phases of offshore wind energy development, with additional sampling efforts five and ten years after construction to assess long term impacts to fisheries resources. *(All RQs)*
  - Ideally, surveys would run continuously pre-construction, through construction, and at least 3 years post-construction in order to follow a Before-After Control-Impact (BACI) design.
- Continue baseline macrofaunal fish and invertebrate surveys during construction and operation to enable an assessment of fish and invertebrate population structures and distributions before and after the offshore wind energy facilities are in place. *(RQs 1-5)*
  - Sampling locations used in baseline research should be maintained through construction and operation in order to maximize the ability to detect changes.
  - New survey stations that encompass elements of the disturbed natural landscape and structural components of the energy installation (e.g. disturbed trenches for cables, buffer zones around structures, anchor surfaces, platform legs) may be added to supplement baseline survey locations.
  - Employ active acoustics (side-scan, DIDSON and similar systems), in addition to trawl and trap surveys, to assess use of infrastructure by small and large pelagics.
  - The existing NEFSC and NEAMAP surveys will likely be prevented from sampling within WEAs due to structural barriers and gear restrictions, but these programs should continue around the WEAs to assess regional changes to fish and invertebrate populations.

- Continue ichthyoplankton surveys through construction and operation to assess changes in the spatiotemporal distribution of fish and invertebrate larvae in the presence of increased noise and vibration. *(RQs 1 & 11)*
    - Maintaining the sampling locations used in baseline research through construction and operation is critical to detecting changes.
- Continue using acoustic telemetry to assess the use of infrastructure for spawning activities and the presence/absence of protected species. *(RQs 1 & 2)*
- Conduct annual habitat surveys (interferometric sonar, video, and grab samples) to assess changes in habitat structure, grain size distribution, and infaunal assemblages during construction and operation. *(RQs 6 & 7)*
    - Focus analysis of habitat data from construction and operational phases of offshore wind energy development on the severity and frequency of sedimentation and scouring around turbines and the exposure of transmission cables, as such changes are likely to have major effects on fisheries resources.
    - Ongoing habitat monitoring efforts should also aim to assess the recovery time of different habitat types from disturbances associated with offshore wind energy development. This will require repeated sampling of fixed locations (as selected by pre-baseline studies and monitored during baseline research).
    - Couple data from ongoing habitat and fish/invertebrate surveys to assess whether turbine foundations act as artificial reefs in attracting fish or hosting invasive species.
- Conduct additional habitat and fish/invertebrate sampling five and ten years after offshore wind energy facility construction to assess long-term changes in benthic habitat and ecosystem structure. *(RQs 1-9)*
- Continue monitoring oceanographic conditions via moorings, CTDs, and ADCPs. *(RQs 8 & 9)*
    - The fixed nature of oceanographic monitoring platforms should make ongoing monitoring efforts relatively low effort and cost.
- Update hydrographic computer models with real-time data about flow fields and oceanographic conditions within and around wind energy areas. *(RQs 8 & 9)*
    - Use hydrographic models to predict long term impacts of offshore wind energy development on local and regional oceanographic conditions.
- Use passive acoustics to monitor the extent and attenuation of noise resulting from construction and operation of offshore wind energy facilities and its effects on the background biological soundscape. *(RQ 11)*
    - Couple acoustic data with fish and invertebrate survey data to assess the effects of noise on the spatiotemporal distributions of adult fish and invertebrates.
    - Couple acoustic data with ichthyoplankton survey data to assess the effects of noise on the density and distribution of fish and invertebrate larvae.
- Continue targeted lobster and elasmobranch surveys and/or tagging throughout construction and operation to assess the impacts of the installations and operation of cables (and, therefore, EMFs) on these species. *(RQ 10)*

- Use acoustic telemetry to assess the in-situ response of elasmobranchs and lobsters to the electromagnetic fields produced by buried cables.
- Acoustic telemetry could also be used to assess the presence/absence of other tagged individuals, including protected species such as Atlantic Sturgeon, as tagged individuals are continuously logged by receiver arrays.

5.3 Preliminary Suggestions for Mitigation Measures:

General suggestions for measures to mitigate possible negative impacts on fisheries resources from offshore wind energy development include the following:

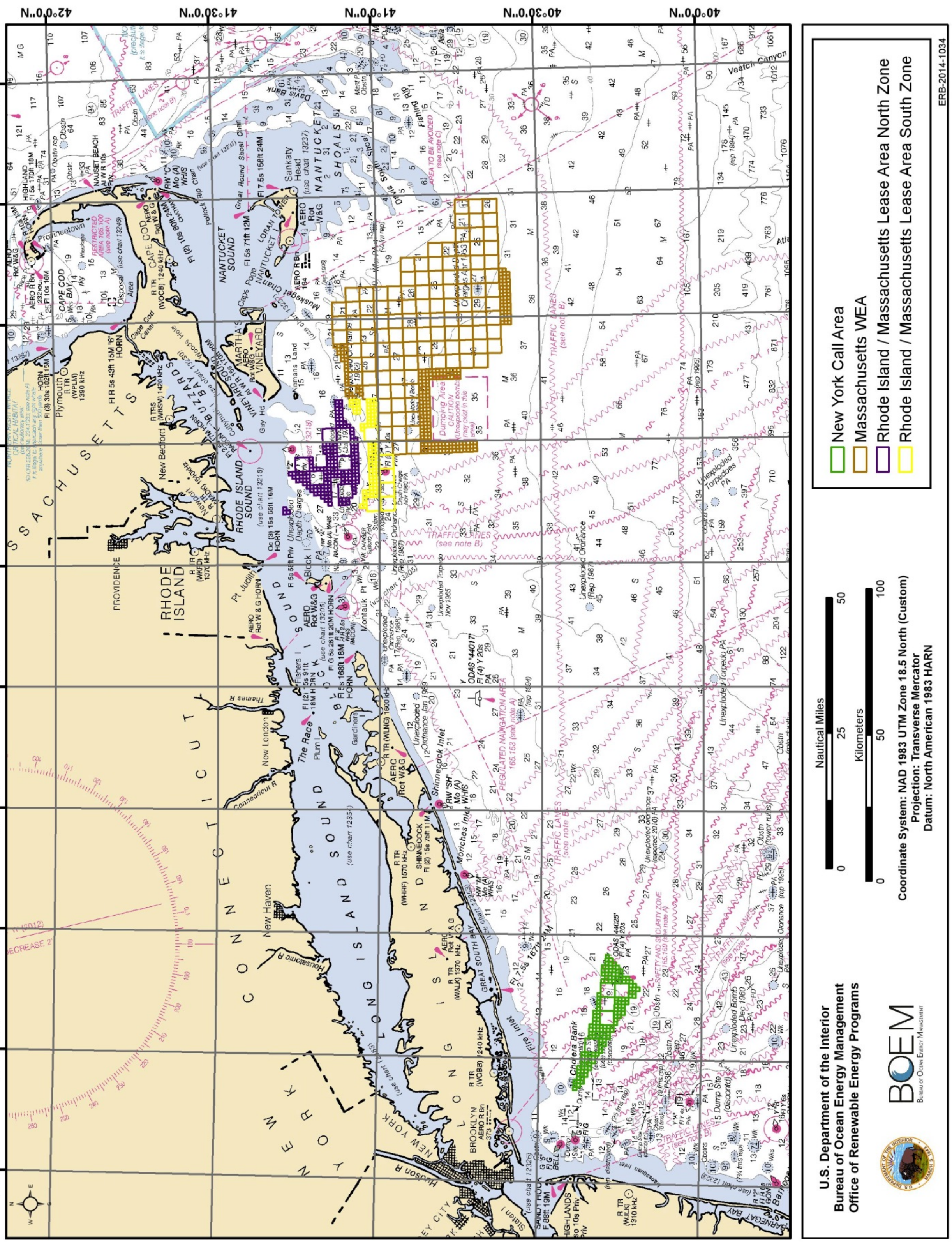
1. Ensure BOEM's Fisheries Pre-Construction Survey Guidelines are followed in a manner that assesses the fisheries ecosystem in each WEA prior to finalizing development plans in order to identify and direct needed mitigation measures (http://www.boem.gov/Fishery-Survey-Guidelines/).
2. Base siting and footprint size decisions on a desire to avoid sensitive fish habitat areas.
3. Utilize turbine layouts that minimize contiguous barriers that may restrict the normal flow of water bodies, larvae, eggs, and other planktonic resource, and that run parallel to the migration routes of key species.
4. Institute measures to prevent and respond to accidents and spills in wind energy areas including reduced speed zones and the creation of pollutant and debris removal plans.

Suggestions specifically related to the construction and operational phases of offshore wind energy facilities include:

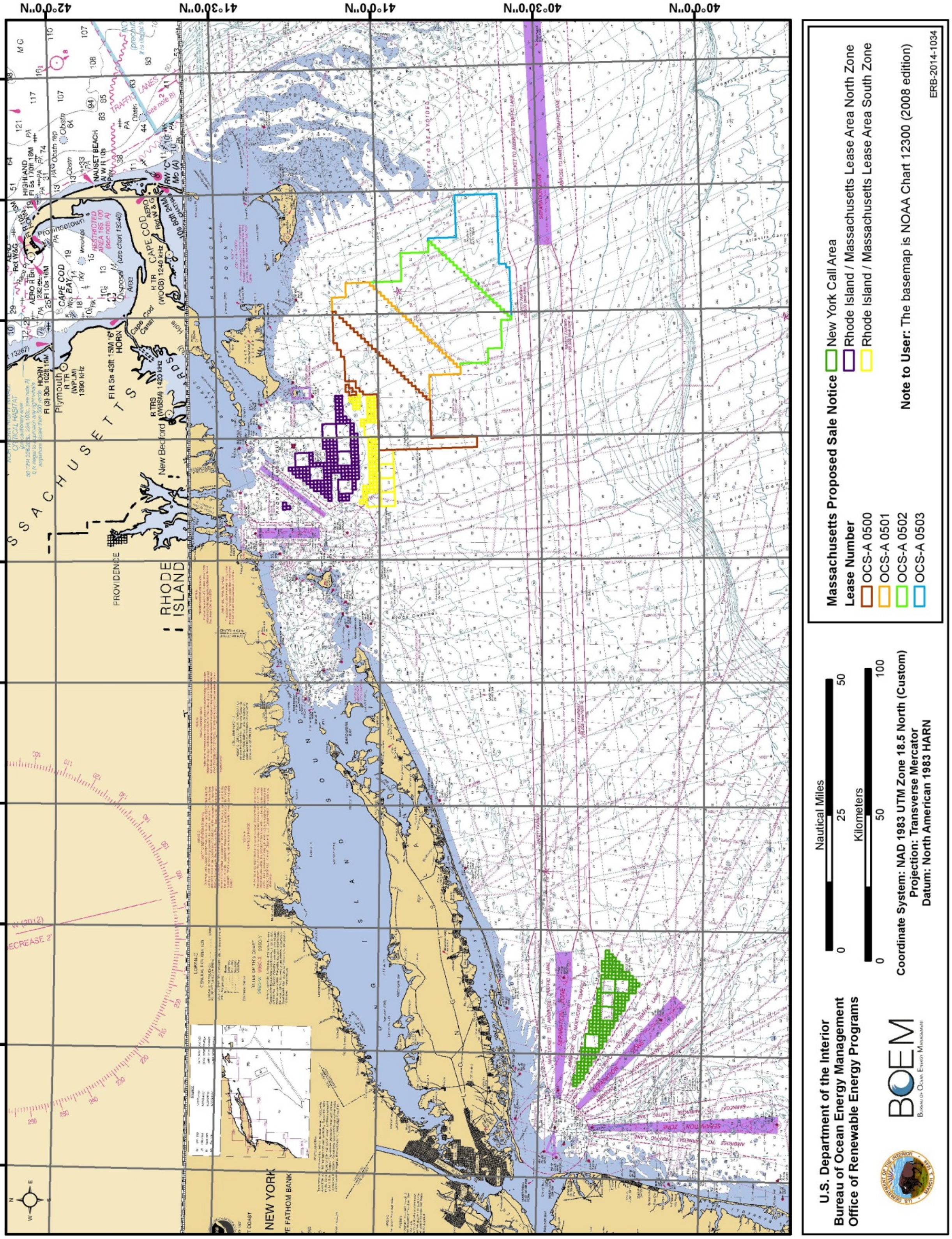
1. Avoid the use of impact pile driving methods, if possible, by utilizing alternatives such as vibratory hammers, drilled shafts, or press-in piling methods.
2. Use bubble nets, acoustic harassment devices, and/or slow start procedures to reduce noise exposure and minimize impacts to mobile organisms.
3. Schedule construction activities to avoid the times of the year when vulnerable species spawn and forage in the WEA.
4. Use midline buoys on anchor sweeps to minimize negative benthic impacts from anchor line sweeps.
5. Bury cables at least 6 feet deep to create a physical barrier between cables and EMF-sensitive species and fishing gear, and to minimize heat radiation into the water column. Require continued monitoring of cable routes and re-burial if cables become uncovered.
6. Use two or more parallel cables in each cable route with electric currents running in opposite directions (bipolar system of transmission) to offset electromagnetic fields and minimize their strength or wrap cables with highly permeable materials or thick materials with high conductivity (e.g. copper) to reduce the strength of electromagnetic fields.
7. During construction and maintenance work, provide vessel operators with detailed maps that identify sensitive habitat areas in which to minimize anchoring.
8. Install scour protection devices around turbine foundations at the time of construction.

9. Utilize hydraulic jet plowing (vs. traditional dredging) during foundation and cable instillations to reduce sediment suspension and transport. Additionally, consider the use of floating turbine foundations to minimize sedimentation impacts.

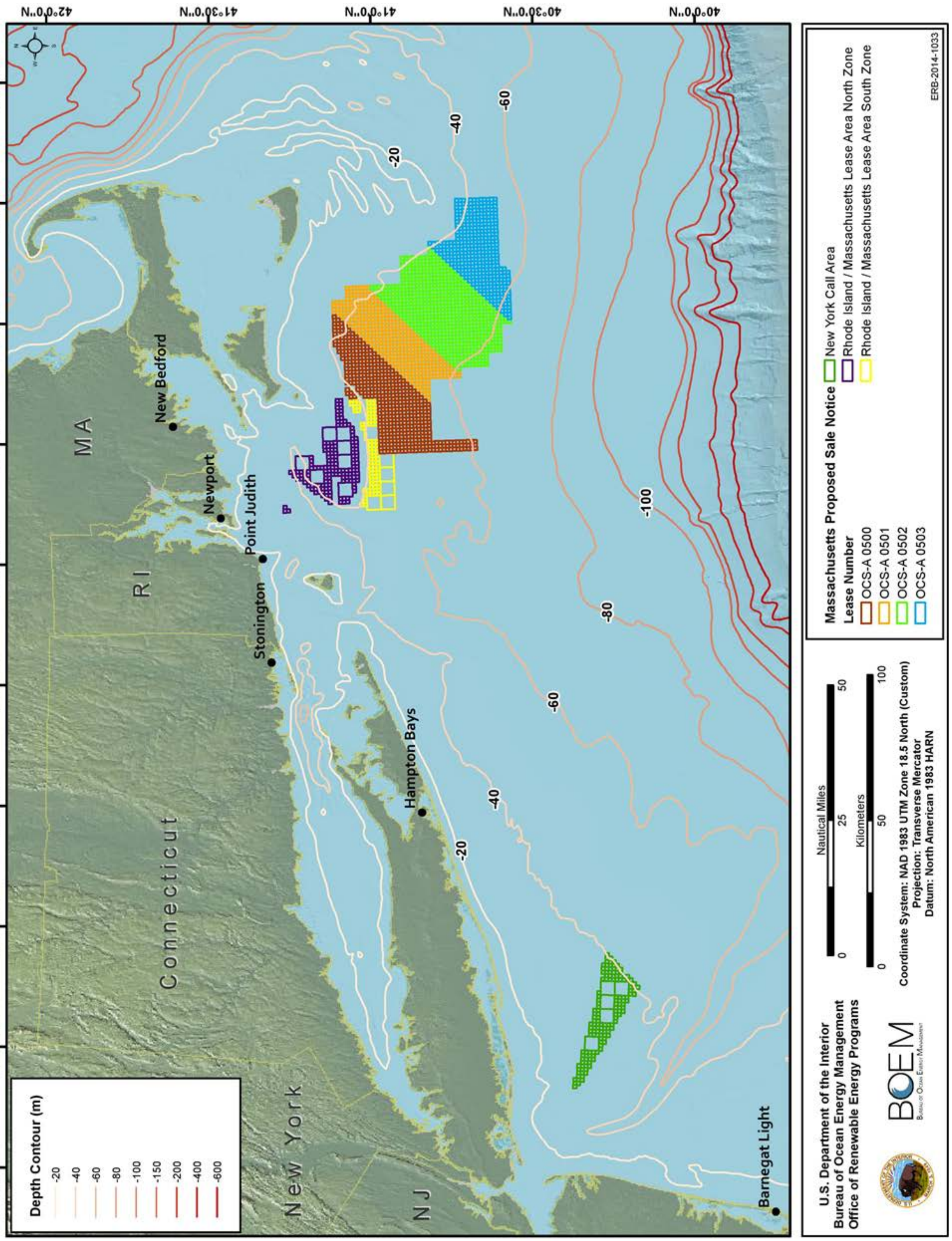
APPENDIX I: LATITUDE AND LONGITUDE NAUTICAL CHART MAP



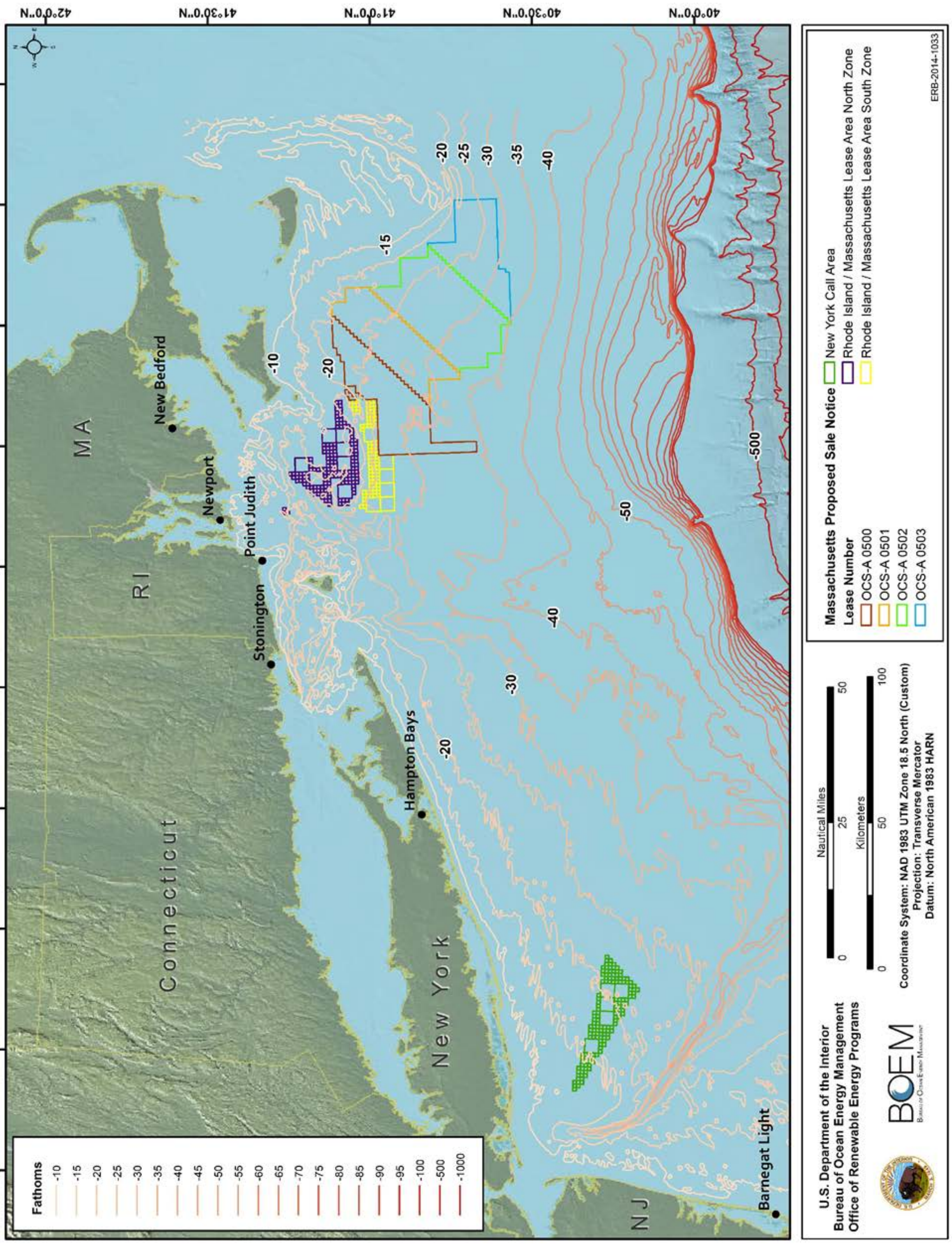
APPENDIX II: LORAN C NAUTICAL CHART MAP



APPENDIX III: METER DEPTH CONTOUR MAP



APPENDIX IV: FATHOM DEPTH CONTOUR MAP



APPENDIX V: CONTACT LIST

To receive input for this project, Commercial Fisheries Research Foundation and Cornell Cooperative Extension of Suffolk County Marine Program staff reached out to members of the fishing industry, the scientific community, and management agencies. Research institutions, agencies, organizations, and groups who were contacted to provide input are listed below.

A. Research Institutions

- University of Rhode Island
- University of Massachusetts Dartmouth, School of Marine Science and Technology
- University of New Hampshire
- University of Connecticut
- University of New England
- Rutgers University
- Cornell University
- Stony Brook University, School of Marine and Atmospheric Sciences
- Virginia Institute of Marine Science
- University of Maryland, Chesapeake Biological Laboratory
- Woods Hole Oceanographic Institution
- Institute for Ocean Conservation Science
- Coonamesset Farm Foundation

B. Management Agencies

- Atlantic States Marine Fisheries Commission
- Mid-Atlantic Marine Fisheries Council
- New England Fisheries Management Council
- National Marine Fisheries Service, Northeast Fisheries Science Center
- Rhode Island Department of Environmental Management
- Massachusetts Division of Marine Fisheries
- Connecticut Department of Energy and Environmental Protection
- New York State Department of Environmental Conservation
- New Jersey Department of Environmental Protection

C. Fishing Industry

- Rhode Island Commercial Fishermen's Association
- Long Island Commercial Fishing Association
- Garden State Seafood Association
- Sakonnet Point Fishermen's Association
- Montauk Boatmen's and Captain’s Association
- Captree Boatmen's Association
- Eastern New England Scallop Association
- Atlantic Offshore Lobstermen's Association
- Rhode Island Lobstermen's Association
- Massachusetts Lobstermen's Association

- Rhode Island Monkfishermen's Association
- Rhode Island Party and Charter Boat Association
- Commercial Trawl Fishermen
- Commercial Scallop Fishermen
- Commercial Gillnet Fishermen
- Commercial Lobster Fishermen
- Party and Charter Fishermen
- Fisheries Gear Manufacturers
- Fisheries Processors

D. Others

- New York Sea Grant Program

APPENDIX VI: OUTREACH LETTER

CFRF COMMERCIAL FISHERIES RESEARCH FOUNDATION
P.O. Box 278, Saunderstown, RI 02874
Phone: (401) 515-4892 | Fax: (401) 515-3537
www.cfrfoundation.org

Date

Name
Affiliation, Title
Address

Re: Identifying Research Needs and Approaches for Assessing Potential Impacts of Offshore Wind Farm Development on Fisheries Resources in the Northeast Region (CFRF BOEM Project #M14PC00005)

Dear Name,

On behalf of the Commercial Fisheries Research Foundation (CFRF), our partners at the federal Bureau of Ocean Energy Management (BOEM), and the Cornell Cooperative Extension Marine Program (CCEMP), I am writing to request your (your organization's) participation in an upcoming project aimed at soliciting, gathering, and summarizing input from leaders in the commercial fishing industry, and fisheries scientists and managers based in the northeast. Specifically the project is aimed at identifying and reporting on: 1) potential impacts on fisheries resources from offshore wind energy facility development in the Cox's Ledge and Cholera Bank WEAs (see attached map); and 2) recommended research approaches for impact assessment.

The project will focus on potential impacts to commercially and ecologically important fish and invertebrate species in these sites (vs. impacts to commercial fishing activities). The goal is to compile and synthesize the input received into a draft best practice document that outlines standard protocols for monitoring and assessing impacts associated with wind energy facilities. Ultimately, this effort is aimed at assisting BOEM with its development of guidelines, protocols and regulations for how offshore wind farm development in the northeast will proceed, including aspects such as wind farm micro-siting, design, size, and construction schedule decisions, as well as how fisheries resource impacts will be evaluated once the wind farms are operational.

In the coming weeks, the CFRF and/or CCEMP staff will be reaching out to you *(your organization)* directly to receive input on the following: 1) which marine fish and invertebrate species may be impacted and how (i.e., what specific construction and/or operation factors contribute to the impact); 2) what should the research priorities be to assess and possibly mitigate negative impacts; and 3) what survey methods and research protocols should be employed to obtain the needed baseline and post-construction monitoring information. Staff will be working to organize a variety of methods to receive input including small group meetings/discussions, individual interviews by phone or in person, or written responses submitted by e-mail or mail.

We hope those that we reach out to will be willing to share their knowledge and expertise on this subject. It is an important opportunity to inform BOEM staff about the concerns associated with potential impacts of offshore wind facility development on key fisheries resources connected with these northeast wind energy areas. It is also an opportunity to assist with developing standardized methods for evaluating impacts on fisheries resources, including survey and research protocols for baseline and monitoring studies, as well as to shape guidelines and regulatory measures related to fisheries resources for offshore wind energy lease holders.

Again, our staff will be reaching out in the coming weeks to establish a means to receive your (your organization's) input. In the meantime, if you have any questions about the project, please feel free to contact me.

Thank you for your consideration, and we look forward to hearing from you.

Sincerely,

Peg Parker

Peg Petruny-Parker, Executive Director

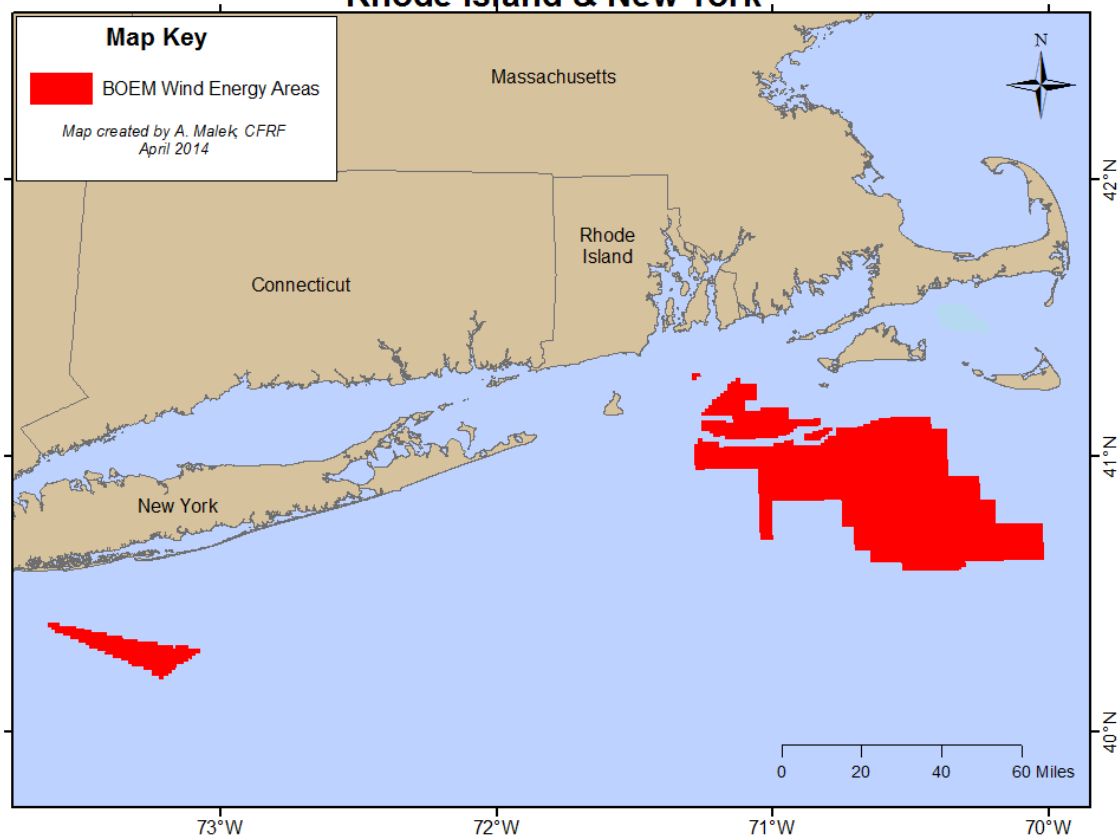
Phone: (401) 515-4662
E-mail: pparker@cfrfoundation.org

Cc:

- David Spencer, CFRF President
- Fred Mattera, CFRF Vice-President
- Emerson Hasbrouck, Project Leader, CCEMP
- Brian Hooker, Contracting Officer's Representative, BOEM

Attachment – Map of RI/MA/NY lease sites

BOEM Wind Energy Areas Offshore Massachusetts, Rhode Island & New York



APPENDIX VII: WRITTEN RESPONSE FORM

Identifying Research Needs and Approaches for Assessing Potential Impacts of Offshore Wind Energy Area Development on Fisheries Resources in the Northeast Region

A project being conducted by the Commercial Fisheries Research Foundation, in partnership with the Cornell Cooperative Extension of Suffolk County Marine Program and the federal Bureau of Ocean Energy Management

Guidelines:

Focal Locations: Wind energy areas off of Rhode Island, Massachusetts, and New York. Please see included maps and charts for reference.

In developing your remarks, please consider all phases of wind energy development including:

- I. Planning and design – wind turbine siting within lease areas (size, number, footprint, area, orientation, spacing, structural integrity)
- II. Construction
- III. Operation
- IV. Decommissioning
- V. Possible collapse or accident – e.g. storms, vessel collision, etc.

Questions:

1. Which marine fish and invertebrate species may be impacted? How might they be impacted? *(Please specify what specific construction and/or operation factors contribute to the impact)*

Species Groups:

- A. Lobster/crab (e.g. American lobster, Jonah crab, etc.)
- B. Scallops/other shellfish (e.g. sea scallop, ocean quahog, etc.)
- C. Demersal fish (e.g. flounder, hake, scup, black sea bass, etc.)
- D. Pelagic forage fish (e.g. herring, mackerel, etc.)
- E. Pelagic predators (e.g. striped bass, bluefish, etc.)
- F. Elasmobranchs (e.g. dogfish, skates, etc.)
- G. Short-lived species (e.g. squid, butterfish, etc.)

2. What times of the year might these potential impacts be most pronounced and why? Consider the following life history factors:

- A. Seasonal migration patterns
- B. Spawning cycles
- C. Mating times/areas
- D. Larval dispersal and settlement
- E. Nursery areas

3. Are there potential ecosystem impacts to these areas that should be considered? Consider the

following dynamics:

A. Sedimentation (benthic communities)
B. Predator/prey relationships
C. Displacement (ecosystem roles)
D. Artificial reef creation
E. Productivity (energy flow)

4. Research Approach:

A. What basic research questions need to be answered for each species group?

B. What standard survey methods and research protocols should be employed to obtain the needed baseline information?

C. What standard survey methods and research protocols should be employed for post construction monitoring?

5. Research Priorities and Findings:

A. Given limited time/resources, what should the research priorities be to assess potential fishery resource impacts?

B. How should the resultant data be compiled, reviewed, synthesized, and shared?

C. What are the potential steps/actions to take to mitigate possible negative impacts on important fisheries resources in these areas?

______________________________   ______________________________

Name (please print or type)   Title/Affiliation

Additional Information:

For more information about the project, or to discuss any of the questions listed above, please contact the:

CFRF
COMMERCIAL FISHERIES
RESEARCH FOUNDATION
P.O. Box 278, Saunderstown, RI 02874
Phone: (401) 515-4892 | Fax: (401) 515-3537
www.cfrfoundation.org

APPENDIX VIII: SAMPLE MEETING AGENDA

Identifying Research Needs and Approaches for Assessing Potential Impacts of Offshore Wind Energy Area Development on Fisheries Resources in the Northeast Region

Joint project being carried out by the Commercial Fisheries Research Foundation and the Cornell Cooperative Extension of Suffolk County Marine Program

BOEM Contract #M14PC00005

Small Group Meeting – Tuesday, Dec. 13, 2014, Commercial Fisheries Center Conference Room

Commercial Fishing Industry Representatives – Rhode Island

Agenda

I. Opening Remarks – P. Parker
   a. Welcome
   b. Overview of project
   c. Questions/Answers/Comments

II. Review of scope of discussion
   a. RI/MA/NY Wind Energy Sites under discussion
   b. Species/types of possible impacts
   c. Research needs/priorities/protocols

III. Which marine fish and invertebrate species may be impacted?
IV. What times of the year might these potential impacts be most pronounced and why?
V. Are there potential ecosystem impacts to these areas that should be considered?
VI. Research Approach:
   - What basic research questions need to be answered for each species group?
   - What standard survey methods and research protocols should be employed to obtain the needed baseline information?
   - What standard survey methods and research protocols should be employed for post-construction monitoring?

VII. Research Priorities and Findings:
   - Given limited time/resources, what should the research priorities be to assess potential fishery resource impacts?
   - How should the resultant data be compiled, reviewed, synthesized, and shared?
   - What are the potential steps/actions to take to mitigate possible negative impacts on important fisheries resources in these areas?

VIII. Recap and other comments
IX. Adjourn

APPENDIX IX: SPECIES OF INTEREST LIST

This species of interest list was created using information from the National Marine Fisheries Service landings data from statistical areas 537, 539, and 612, as well as catch information from the National Marine Fisheries Service Northeast Fisheries Science Center's spring and autumn bottom trawl surveys (R/V Bigelow). Species were also added to this list through written responses and meeting discussions. Species were grouped into taxonomic and ecological categories including:

A. Crustaceans (e.g. American lobster, Jonah crab, etc.)
B. Shellfish (e.g. sea scallop, ocean quahog, etc.)
C. Demersal Fish (e.g. flounder, hake, scup, black sea bass, etc.)
D. Pelagic Forage Fish (e.g. herring, mackerel, etc.)
E. Pelagic Predators (e.g. striped bass, bluefish, tuna, etc.)
F. Elasmobranchs (e.g. dogfish, skates, sharks, etc.)
G. Short Lived Species (e.g. squid, butterfish, etc.)
H. Other

Species with ecologically threatened statuses or commercially depleted stock statuses have been indicated using the following collored asterisks:

* Denotes a threatened species (endangered, vulnerable, etc.)
* Denotes species listed in overfishing status in 2013 in these wind energy areas
* Denotes species listed in overfished status in 2013 in these wind energy areas
* Denotes a species previously listed as rebuilt in these wind energy areas

A. Crustaceans (e.g. American lobster, Jonah crab, etc.)
- American lobster, *Homarus americanus*
- Jonah crab, *Cancer borealis*
- Rock crab (peekytoe crab), *Cancer irroratus*
- Spider crab, *Majoidea spp.*
- Lady crab (calico or ocellated crab), *Ovalipes ocellatus*
- Green crab, *Carcinus maenas*
- Blue crab, *Callinectes sapidus*
- Horseshoe crab, *Limulidae spp.*
- Mantis shrimp, *Stomatopoda spp.*
- Pandalid shrimp, *Pandalidae spp.*
- Caridean shrimp, *Caridea spp.*
- Bristled longbeak, *Dichelopandalus leptocerus*
- Sevenspine bay shrimp (sand shrimp), *Crangon septemspinosa*

B. Shellfish (e.g. sea scallop, ocean quahog, etc.)
- Sea scallop, *Placopecten magellanicus*
- Ocean quahog, *Arctica islandica*
- Atlantic surfclam, *Spisula solidissima*

- Atlantic jackknife clam (razor clam, bamboo clam), *Ensis directus*
- Moon snail, *Naticidae spp.*
- Waved whelk (common whelk), *Buccinum undatum*
- Knobbed whelk, *Busycon carica*
- Channeled whelk, *Busycotypus canaliculatus*
- Blue mussel, *Mytilus edulis*
- Soft shell clam, *Mya arenaria*
- Eastern oyster, *Crassostrea virginica*

C. Demersal Fish (e.g. flounder, hake, scup, black sea bass, etc.)

* Atlantic sturgeon, *Acipenser oxyrinchus oxyrinchus*
    * Endangered species
* Shortnose sturgeon, *Acipenser brevirostrum*
    * Endangered species
** Atlantic cod, *Gadus morhua*
    * Overfishing in Gulf of Maine and Georges Bank
    * Overfished in Gulf of Maine and Georges Bank
** Haddock, *Melanogrammus aeglefinus*
    * Overfishing in Gulf of Maine
    * Rebuilt in 2011 in Georges Bank
* Polluck (saithe), *Pollachius spp.*
    * Rebuilt in 2011 in the Northeast
* Scup (porgy), *Stenotomus chrysops*
    * Rebuilt in 2009 in the Atlantic Coast
* Silver hake, *Merluccius bilinearis*
    * Rebuilt in 2007 in the Northeast
* Wolffish, *Anarhichas lupus*
    * Overfished in New England
* Ocean pout, *Zoarces americanus*
    * Overfished in New England
* Monkfish (goosefish), *Lophiidae spp.*
    * Rebuilt in 2008 in the North and South
* Atlantic halibut, *Hippoglossus hippoglossus*
    * Overfished in New England
*** Windowpane flounder, *Scophthalmus aquosus*
    * Overfishing in Gulf of Maine and Georges Bank
    * Overfished in Gulf of Maine and Georges Bank
    * Rebuilt in 2012 in Southern New England
* Winter flounder, *Pseudopleuronectes americanus*
    * Overfished in Southern New England and Mid Atlantic
*** Yellowtail flounder, *Pleuronectes ferruginea*
    * Overfishing in Cape Cod, Gulf of Maine, and Georges Bank
    * Overfished in Cape Cod, Gulf of Maine, and Georges Bank
    * Rebuilt in 2012 in Southern New England and Mid Atlantic
** Witch flounder (grey sole), *Glyptocephalus cynoglossus*
    * Overfishing in New England

* Overfished in New England

- Summer flounder (fluke), *Paralichthys dentatus*
- Fourspot flounder, *Hippoglossina oblonga*
- American plaice (dab), *Hippoglossoides platessoides*
- Gulf Stream flounder, *Citharichthys arctifrons*
- Smallmouth flounder, *Etropus microstomus*
- Anglerfish, *Lophiiformes spp.*
- Northern stargazer, *Astroscopus guttatus*
- Toadfish, *Batrachoididae spp.*
- Striped sea robin, *Prionotus evolans*
- Northern sea robin, *Prionotus carolinus*
- Sea raven, *Hemitripteridae spp.*
- Longhorn sculpin, *Myoxocephalus octodecimspinosus*
- Shorthorn sculpin, *Myoxocephalus scorpius*
- Red hake, *Urophycis chuss*
- White hake, *Urophycis tenuis*
- Spotted hake, *Urophycis regia*
- Whiting, *Merlangius merlangus*
- Black whiting, *Sillaginodes punctata*
- King whiting (kingfish), *Menticirrhus saxatilis*
- Atlantic Tomcod, *Microgadus tomcod*
- Red porgy, *Pagrus pagrus*
- Black sea bass, *Centropristis striata*
- Cunner, *Tautogolabrus adspersus*
- Tautog, *Tautoga onitis*
- Black drum, *Pogonias cromis*
- Golden tilefish, *Lopholatilus chamaeleonticeps*
- Blueline tilefish, *Caulolatilus microps*
- Sand tilefish, *Malacanthus plumieri*
- Planehead filefish, *Stephanolepis hispidus*
- John Dory, *Zeus faber*
- Conger eel, *Congridae spp.*
- American eel, *Anguilla rostrata*
- Fawn cusk eel, *Lepophidium profundorum*
- Sand eel (sand lance), *Hyperoplus/Gymnammodytes/Ammodytes spp.*
- Weakfish (squeteague, sea trout), *Cynoscion regalis*
- Spot (spot croaker), *Leiostomus xanthurus*
- Atlantic croaker, *Micropogonias undulatus*
- Triggerfish, *Balistidae spp.*
- Northern puffer, *Sphoeroides maculatus*
- Leatherjacket, *Oligoplites saurus*
- Acadian redfish, *Sebastes fasciatus*
- Golden redfish, *Sebastes norvegicus*
- Red snapper, *Lutjanus campechanus*
- Spadefishes, *Ephippidae spp.*
- Inshore lizardfish, *Synodus foetens*

- Snakefish, *Trachinocephalus myops*
- Pinfish, *Lagodon rhomboides*
- Blue runner, *Caranx crysos*
- Fourbeard rockling, *Enchelyopus cimbrius*
- Wrymouth, *Cryptacanthodes maculatus*
- Northern sennet, *Sphyraena borealis*
- Dwarf goatfish, *Upeneus parvus*
- Cornetfish (flutemouth), *Fistularia spp.*
- Atlantic moonfish, *Selene setapinnis*
- Short bigeye, *Pristigenys alta*
- Spotted driftfish, *Ariomma regulus*
- Silver rag driftfish, *Ariomma bondi*
- Wreckfish, *Polyprionidae spp.*
- Lumpfish (lumpsuckers), *Cyclopteridae spp.*
- Three spined stickleback, *Gasterosteus aculeatus*
- American silver perch, *Bairdiella chrysoura*
- Sheepshead minnow, *Cyprinodon variegatus*
- Seahorses (pipefish, sea dragons), *Syngnathidae spp.*

D. Pelagic Forage Fish (e.g. herring, mackerel, etc.)
- Atlantic herring, *Clupea harengus*
- Blueback herring, *Alosa aestivalis*
- Round herring, *Etrumeus sadina*
- Alewife, *Alosa pseudoharengus*
- Atlantic mackerel, *Scomber scombrus*
- Spanish mackerel, *Scomberomorus maculatus*
- Chub mackerel, *Scomber japonicus*
- Gizzard shad, *Dorosoma cepedianum*
- American shad, *Alosa sapidissima*
- Hickory shad, *Alosa mediocris*
- Round scad, *Decapterus punctatus*
- Rough scad, *Trachurus lathami*
- Bigeye scad, *Selar crumenophthalmus*
- Atlantic menhaden, *Brevoortia tyrannus*
- Atlantic saury, *Scomberesox saurus*
- Atlantic silverside, *Menidia menidia*
- Bay anchovy, *Anchoa mitchilli*

E. Pelagic Predators (e.g. striped bass, bluefish, etc.)

** Atlantic salmon, *Salmo salar*

    * Endangered species
    * Overfished in New England

** Bluefin tuna, *Thunnus thynnus*

    * Overfishing in West Atlantic
    * Overfished in West Atlantic

** Albacore, *Thunnus alalunga*

* Overfishing in North Atlantic
* Overfished in North Atlantic
* Swordfish, *Xiphias gladius*
* Rebuilt in 2009 in the North Atlantic
* Bluefish, *Pomatomus saltatrix*
* Rebuilt in 2008 in the Atlantic Coast
- Striped bass, *Morone saxatilis*
- Atlantic Bonito, *Sarda sarda*
- Little tunny tuna, *Euthynnus alletteratus*
- Bigeye tuna, *Thunnus obesus*
- Yellowfin tuna, *Thunnus albacares*
- Mahi mahi (dolphin), *Coryphaena hippurus*
- Cobia, *Rachycentron canadum*
- Wahoo, *Acanthocybium solandri*
- King mackerel, *Scomberomorus cavalla*
- White marlin, *Tetrapturus albidus*
- Blue marlin, *Makaira nigricans*

F. Elasmobranchs (e.g. dogfish, skates, sharks, etc.)
* Basking shark, *Cetorhinus maximus*
* Vulnerable species
* Spiny dogfish, *Squalus acanthias*
* Rebuilt in 2011 in the Northeast
* Winter skate, *Leucoraja ocellata*
* Overfishing in Georges Bank and Southern New England
** Thorny skate, *Amblyraja radiate*
* Overfishing in the Gulf of Maine
* Overfished in New England
- Smooth dogfish, *Mustelus canis*
- Porbeagle, *Lamna nasus*
- Thresher shark, *Alopius vulpinus*
- Bigeye Thresher, *Alopias superciliosus*
- Great white shark, *Carcharodon carcharias*
- Shortfin mako shark, *Isurus oxyrinchus*
- Blue shark, *Prionace glauca*
- Sandbar shark, *Carcharhinus plumbeus*
- Dusky shark, *Carcharhinus obscurus*
- Scalloped hammerhead shark, *Sphyrna lewini*
- Little skate, *Leucoraja erinacea*
- Barndoor skate, *Dipturus laevis*
- Clearnose skate, *Raja eglanteria*
- Roughtail stingray, *Dasyatis centroura*
- Round stingray, *Urolophus halleri*
- Bullnose ray, *Myliobatis freminvillii*
- Atlantic torpedo ray, *Torpedo nobiliana*

G. Short Lived Species (e.g. squid, butterfish, etc.)
- Butterfish, *Peprilus triacanthus*
- Longfin squid, *Doryteuthis (Amerigo) pealeii* (formerly *Loligo pealeii*)
- Shortfin squid, *Illex spp.*
- Bobtail squid (dumpling and stubby squid), *Sepiolidae* and *Rossia spp.*

H. Other
- Ocean sunfish, *Mola mola*
- Common octopus, *Octopus vulgaris*

APPENDIX X: TOP TEN SPECIES LANDED IN RHODE ISLAND AND NEW YORK[20]

New York Commercial Fishing Top 10 Landed Species by Pounds (2013)

Year	AFS Species Name	Pounds
2013	SQUID, LONGFIN	4,828,205
2013	SCUP	4,577,932
2013	CLAM, ATLANTIC SURF	3,452,496
2013	HAKE, SILVER	2,380,120
2013	WHELK	2,073,001
2013	CLAM, NORTHERN QUAHOG	1,932,373
2013	SKATES	1,881,619
2013	TILEFISH, GOLDEN	1,466,281
2013	GOOSEFISH	1,425,514
2013	MOLLUSKS	1,289,667

New York Commercial Fishing Top 10 Landed Species by Value (2013)

Year	AFS Species Name	Dollars
2013	CLAM, NORTHERN QUAHOG	13,474,804
2013	SQUID, LONGFIN	5,975,821
2013	TILEFISH, GOLDEN	4,672,505
2013	OYSTER, EASTERN	4,148,769
2013	BASS, STRIPED	3,393,905
2013	FLOUNDER, SUMMER	3,231,889
2013	SCUP	2,970,263
2013	SCALLOP, SEA	2,601,571
2013	CLAM, ATLANTIC SURF	2,410,205
2013	HAKE, SILVER	1,908,938

Rhode Island Commercial Fishing Top 10 Landed Species by Pounds (2013)

Year	AFS Species Name	Pounds
2013	HERRING, ATLANTIC	27,881,148
2013	SQUID, LONGFIN	12,586,996
2013	SKATE, LITTLE	8,196,699
2013	SCUP	7,357,223
2013	SKATES	4,711,133
2013	CRAB, JONAH	4,397,735

2013	SHELLFISH	3,688,498
2013	GOOSEFISH	2,824,859
2013	HAKE, SILVER	2,429,908
2013	FLOUNDER, SUMMER	2,192,689

Rhode Island Commercial Fishing Top 10 Landed Species by Value (2013)

Year	AFS Species Name	Dollars
2013	SCALLOP, SEA	18,657,784
2013	SQUID, LONGFIN	13,172,234
2013	LOBSTER, AMERICAN	9,731,977
2013	FLOUNDER, SUMMER	6,752,337
2013	CLAM, NORTHERN QUAHOG	5,032,882
2013	HERRING, ATLANTIC	4,782,395
2013	OYSTER, EASTERN	4,265,031
2013	SCUP	3,668,517
2013	CRAB, JONAH	3,179,956
2013	GOOSEFISH	2,733,107

ENDNOTES

[1] The Cornell team focused on outreach to fishing industry representatives from New York and New Jersey, and key fisheries researchers and managers based in New York. The CFRF staff conducted outreach for the rest of the targeted list including scientists based at institutions and agencies on the list outside of New York, the staff and members of the NEFMC, MAFMC, and ASMFC, and fishing industry leaders from ports in Rhode Island.

[2] Additionally, online sources such as the National Marine Fisheries Service Essential Fish Habitat Mapper and The Nature Conservancy's Northwest Atlantic Marine Ecoregional Assessment Spatial Data Map Viewer were utilized to obtain site specific information on the species and habitat present in the WEAs.

[3] This includes the NMFS NEFSC R/V Bigelow spring and fall surveys, VIMS NEAMAP Program, NMFS Observer Program, state surveys inside state waters, and surveys conducted on occasion by researchers outside of government.

[4] Fishermen reported that they often do not take the time to report their catch in terms of all the Statistical Areas they fished on a given fishing trip, or to enter data very accurately.

[5] Regulations prevent the landing of female lobsters with eggs. One commenter on this point said there were 10 times more eggers on Cox's Ledge than anywhere else in the area and the area was avoided by lobstermen because so many lobsters brought up in traps could not be kept.

[6] A study concerning American lobster's ability to detect EMFs was carried out in tanks, but the results were inconclusive (http://tethys.pnnl.gov/publications/effects-electromagnetic-fields-fish-and-invertebrates).

[7] Scup, founder, and monkfish were reported by fishermen as being abundant in the area around the southwestern portion of the Cox's Ledge WEA.

[8] Little skate, winter skate, monkfish, and whiting were reported by fishermen as being present in the Cox's Ledge WEA year round.

[9] Cod spawning has been documented in the Cox's Ledge area during January and April 2007 and in the NY Bight during the winter and spring of 2007-2008 (Kovach et al., 2010)

[10] Fishermen referred to the Deep Hole (or Mud Hole) in discussions. From their perspectives, the Deep Hole is an area just on the western edge of the Cox's Ledge WEA, between Cox's Ledge and Block Island, RI (approximately between Latitude 41.00-41.10 degrees N and between Longitude 71.10-71.30 degrees W). Fishermen also referred to the "Fingers" area as the area northeast of the Deep Hole or Mud Hole. This area is noted for its relatively high abundance of yellow tail, winter, and windowpane flounders. The area southwest of the Deep Hole or Mud Hole is noted for relatively high abundances of black sea bass, scup and codfish. Personal communication, Fred Mattera, member of RI commercial fishing industry.

[11] RI fishermen referred to a study which found herring exhibited avoidance responses of 40-50 miles from construction activities.

[12] Fishermen referred to Cholera Bank in discussions. The Cholera Bank fishing area encompasses the southeastern end of the Cholera Bank WEA, and extends further south out to about 35 fathoms. Generally speaking the Cholera Bank fishing area is southwest of Fire Island inlet to south of East Rockaway Inlet (approximately between Latitude 40.30 – 40.20 degrees N and between Longitude 73.25-73.50 degrees W). Personal communication, Fred Mattera, member of RI commercial fishing industry.

[13] Deep Hole was considered to be a productive highway for squid, scup, whiting, and all flounder species during spring and fall runs.

[14] Scup and black sea bass may benefit from the structure provided by the wind farms in terms of habitat – other species such as Atlantic mackerel, bluefish, and spiny dogfish could be attracted to structures because of the high abundance of prey.

[15] It was speculated that this introduction could be through adhesion to the hulls of ships or release of ballast water.

[16] In discussions, fishermen estimated that approximately 50% of the landings in Point Judith originate from the Cox's Ledge WEA and parts of the WEA Southwest of Nantucket Shoals.

[17] One suggestion was to follow the example of the scallop RSA Program. This involves scientists (Council Plan Development Team), managers (Council Oversight Committee), and industry members (advisors from the scallop industry). Research priorities are identified, projects are solicited, technical experts review proposals, and awards are issued through a management review process that includes fishermen and Council members.

[18] In the Cape Wind project there will be a speed limit of ten knots for all vessels (BOEM DOE/EIS-0470, 2012).

[19] These methods will be employed in construction at the Cape Wind project (BOEM DOE/EIS-0470, 2012).

[20] From NOAA NMFS Office of Science and Technology - Accessed March 15, 2015 through the following link: http://www.st.nmfs.noaa.gov/commercial-fisheries/commercial-landings/annual-landings/ The annual commercial landings statistics for each species was queried individually by state creating a spreadsheet of metric tons, pounds and dollar value for all landed species. The top 10 species in pounds and value from the query results were used to generate the tables in Appendix XI. 2013 is the most recent year for which data is available.

APPENDIX XI: REFERENCES

Reference documents were grouped into categories based on the sources from which they came and the subject(s) they contain, these categories include:

- BOEM Documents
- Electromagnetic Fields (EMF)
- European, Cape Wind, and Block Island Wind Farms
- Fish Aggregation and Artificial Reefs
- General Sources
- Habitat
- Noise, Vibration, and Pile Driving
- Research Protocols and Recommendations
- Scouring and Sedimentation
- Species Impacts

BOEM Documents:

Bureau of Ocean Energy Management. Office of Renewable Energy Programs. United States of America. Development of Mitigation Measures to Address Potential Use Conflicts Between Commercial Wind Energy Lessees/Grantees and Commercial Fishermen on the Atlantic Outer Continental Shelf. By Peggy Farrell, Sarah Bowman, Jennifer Harris, David Trimm, and William Daughdrill. 2014. (BOEM, 2014)

Bureau of Ocean Energy Management. *Renewable Energy GIS Data*. Renewable Energy Programs Mapping & Data. Web. 1 Apr. 2015. (BOEM, April 2015)

Bureau of Ocean Energy Management. *Renewable Energy Research Ongoing Studies*. Web. 30 Jan. 2015. (BOEM, March 2015)

Bureau of Ocean Energy Management. United States of America. Regulation and Enforcement. Guidelines for Information Requirements for a Renewable Energy Construction and Operations Plan. 2010. (BOEM, 2010)

Bureau of Ocean Energy Management. United States of America. West Coast Environmental Protocols Framework: Baseline and Monitoring Studies. 2012. (BOEM, 2012)

McCann, J. (2012). Developing Environmental Protocols and Modeling Tools to Support Ocean Renewable Energy and Stewardship. U.S. Dept. of the Interior, Bureau of Ocean Energy Management, Office of Renewable Energy Programs, Herndon, VA., OCS Study BOEM 2012-082, 626 pp. (McCann, 2012)

Rein C.G., Lundin, A.S., Wilson, S.J.K., Kimbrell, E. 2013. Offshore Wind Energy Development Site Assessment and Characterization: Evaluation of the Current Status and European Experience. U.S. Dept. of the Interior, Bureau of Ocean Energy Management, Office of Renewable Energy Programs, Herndon, VA. OCS Study BOEM 2013-0010.

[273] pp. (Rein et al., 2013)

Electromagnetic Fields:

Fisher, Cameron, and Michael Slater. *Effects of Electromagnetic Fields on Marine Species: A Literature Review*. Oregon Wave Energy Trust, 2010. (Fisher and Slater, 2010)

Normandeau, Exponent, T. Tricas, and A. Gill. 2011. Effects of EMFs from Undersea Power Cables on Elasmobranchs and Other Marine Species. U.S. Dept. of the Interior, Bureau of Ocean Energy Management, Regulation, and Enforcement, Pacific OCS Region, Camarillo, CA. OCS Study BOEMRE 2011-09. (Normandeau et al., 2011)

Woodruff D.L., V.I. Cullinan, A.E. Copping, and K.E. Marshall. 2013. Effects of Electromagnetic Fields on Fish and Invertebrates Task 2.1.3: Effects on Aquatic Organisms Fiscal Year 2012 Progress Report Environmental Effects of Marine and Hydrokinetic Energy. PNNL-22154, Pacific Northwest National Laboratory, Richland, WA. (Woodruff et al., 2013)

European, Cape Wind, and Block Island Wind Farms:

Andersson, Mathias H., and Marcus C. Ohman. "Fish and Sessile Assemblages Associated with Wind-turbine Constructions in the Baltic Sea." *Marine and Freshwater Research* 61 (2010): 642-50. (Andersson and Ohman, 2010)

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The Department of the Interior Mission

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The Bureau of Ocean Energy Management

As a bureau of the Department of the Interior, the Bureau of Ocean Energy (BOEM) primary responsibilities are to manage the mineral resources located on the Nation's Outer Continental Shelf (OCS) in an environmentally sound and safe manner.

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