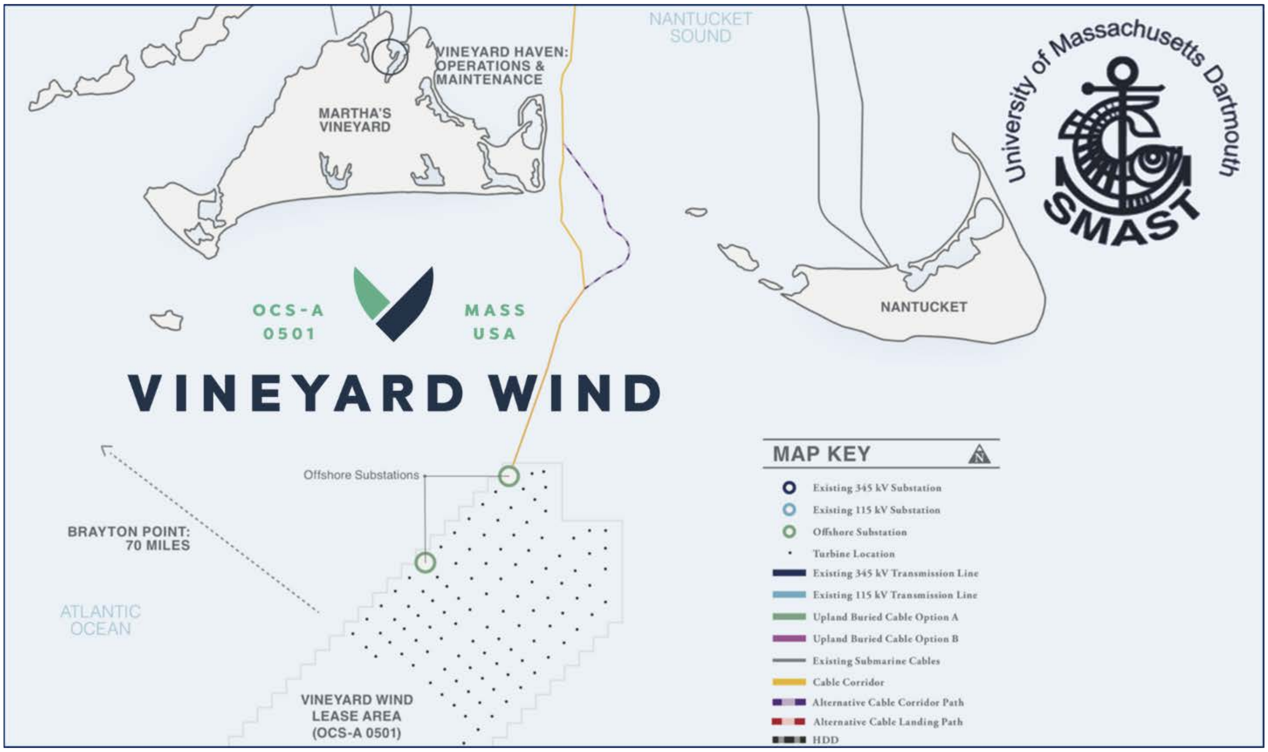
RECOMMENDATIONS FOR PLANNING PRE- AND POST-CONSTRUCTION ASSESSMENTS OF FISHERIES IN THE VINEYARD WIND OFFSHORE WIND LEASE AREA



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1. Background

Vineyard Wind contracted the School for Marine Science and Technology (SMAST) for 'Phase 1: Development of Monitoring Plan', which involved collaborating with the fishing industry, regulatory agencies and Vineyard Wind to plan pre- and post-construction assessments of fisheries, associated ecological conditions, and socio-economic aspects of fisheries, in and around the Vineyard Wind offshore wind lease area, as designated by the US Bureau of Ocean Energy Management, on the US Outer Continental Shelf. The purpose of this report is to help answer questions and provide information that can further the public understanding of potential impacts of offshore wind development and possible means of mitigation of any such impacts. This information will help inform future permitting and public policy decisions. This effort is part of a larger framework of monitoring and assessment that is expected to be augmented by other sources of funding.

A scoping exercise was completed to identify what questions and information would be most useful in achieving the purpose of this assessment work. In developing this scope, SMAST researchers solicited input from the various fisheries active in the region, policy makers, regulators and academia. The main outcome of the scoping phase will be a plan to conduct one or more pre- and post-construction assessments, and a schedule and budget to conduct the assessments.

SMAST organized and hosted a series of workshops, with fishermen and regulators to present a relatively expansive set of monitoring component options and to identify which elements are most important to local fisheries and which are most important to regulators. The outreach mechanism was email, phone calls, networking at other meetings (e.g., New England Fishery Management Council process) and port visits (e.g., New Bedford and Pt Judith). Outreach included commercial and recreational fishermen and fishing organizations involved in fisheries that are active in the development area (e.g., squid-mackerel-butterfish, scup-sea bass-fluke, southern New England groundfish, scallop, monkfish-skate, lobster-crab). Monitoring components include (but are not be limited to) fishery assessments, fishery resources surveys, tagging, oceanographic monitoring and modeling, socio-economic analysis, and geostatistical integration of monitoring components. Optional design features such as important indicator species and seasonality of monitoring were presented and discussed.

<u>State and Federal Guidance</u>

Massachusetts

The MA Division of Marine Fisheries produced a report on "*Recommended regional scale studies related to fisheries in the Massachusetts and Rhode Island-Massachusetts offshore Wind Energy Areas.*" (MADMF 2018). The report recommends the standardization of monitoring protocols among offshore wind energy lease sites to facilitate the evaluation of regional impacts. The report also identifies fish and invertebrate species of interest by season (Table 1) and provides a list of important species to include in the monitoring plan (Cod, summer flounder, winter flounder, yellowtail flounder, monkfish, ocean pout, red hake, black sea bass, longfin squid, scup, Jonah crab, lobster, ocean quahog, sea scallop, bluefin tuna, sharks, skates, prey species (sand lance, herring, menhaden, mackerel, epifauna).

Table 1. Dominant species in RI-MA Wind Energy Areas from 2003-2014 trawl surveys (from MADMF 2018).

Cold Season (winter and spring)	**Warm Season (summer and fall)**
Little skate (both)	Little skate (both)
Silver hake (MA)	Silver hake (MA)
Winter skate (both)	Winter skate (MA)
Atlantic herring (both)	Butterfish (both)
Longhorn sculpin (RI-MA)	Red hake (MA)
Ocean pout (RI-MA)	Scup (both)
Windowpane flounder (RI-MA)	Longfin squid (both)
Yellowtail flounder (RI-MA)	Spiny dogfish (both)
	Northern sea robin (RI-MA)
	Sea scallop (RI-MA)

The general approach to developing a Vineyard Wind monitoring plan was presented to the Massachusetts Fisheries Working Group on Offshore Energy (September 2018). The Working Group chair requested that monitoring plans should be coordinated among developers of adjacent lease areas to support comparisons and regional impact analyses.

Rhode Island

According to the RI Ocean Special Area Management Plan guidelines (RICRMC 2010), the Rhode Island Coastal Resources Management Council in coordination with the Joint Agency Working Group "*shall determine requirements for monitoring prior to, during, and post construction. Specific monitoring requirements shall be determined on a project by-project basis and may include but are not limited to the monitoring of: coastal processes and physical oceanography, underwater noise, benthic ecology, avian species, marine mammals, sea turtles, fish and fish habitat, commercial and recreational fishing, recreation and tourism, marine transportation, navigation and existing infrastructure, and cultural and historic resources.*

…biological assessment of commercially and recreationally targeted species shall be required within the project area for all Offshore Developments. This assessment shall assess the relative abundance, distribution, and different life stages of these species at all four seasons of the year. This assessment shall comprise a series of surveys, employing survey equipment and methods that are appropriate for sampling finfish, shellfish, and crustacean species at the project's proposed location. Such an assessment shall be performed at least four times: pre-construction (to assess baseline conditions); during construction; and at two different intervals during operation (i.e. 1 year after construction and then post-construction). At each time this assessment must capture all four seasons of the year. This assessment may include evaluation of survey data collected through an existing survey program, if data are available for the proposed site. The Council will not require this assessment for proposed projects within the Renewable Energy Zone that are proposed within 2 years of the adoption of the Ocean SAMP."

Bureau of Ocean Energy Management

BOEM (2013) provides "*Guidelines for Providing Information on Fisheries for Renewable Energy Development on the Atlantic Outer Continental Shelf*". The guidelines recommend the development of a fishery survey, coordination with BOEM staff and other agencies, outreach to potentially affected fishing groups, and determination of species of interest within the leasehold and potential effects. The fishery survey should include:

- seasonal presence/absence of threatened or endangered fish listed under the Endangered Species Act and species of concern by National Marine Fisheries Service (www.nmfs.noaa.gov/pr/species/fish);
- seasonal presence/absence of commercially and recreationally-important fish and shellfish;
- presence of prey species for threatened, endangered, commercially and recreationally-important fish and shellfish;
- presence of habitat important to life history of present species (e.g., nursery grounds, spawning grounds, feeding grounds, etc.);
- spatial extent, volume, and effort of commercial and recreational exploitation of fishery resource in the area of potential effects; and
- migration corridors for fish and crustaceans.

BOEM guidelines encourage the use existing data and collaboration with other developers, research institutions, and government agencies. The guidelines also recommend specific survey protocols (Table 2).

Table 2a. Recommended trawl survey protocols (from BOEM 2013).

Focus	Establish baseline data on the meso-scale distribution and abundance of fish species in the area of potential effect resulting from activities in a SAP, COP, or GAP.
Methodology	Otter Trawl Survey
Description of Methodology	• Use Before/After Control Impact (BACI) design principles to establish multiple control locations outside of the project area. • Select control locations that have similar bottom types and benthic habitat as project area trawl locations. • Trawl locations from random station grid. • Conduct surveys a minimum of four times/year. • Select baseline trawl locations and paths so that you can follow the same route after construction. • Sample all fish species, with particular attention paid to commercially, recreationally, and ecologically important species • Obtain a sampling of weight and length of species. • Use a one inch knotless cod end liner. • Ensure a trawl speed of 2.9 – 3.3 knots. • Ensure a trawl duration of no more than 20 minutes (depending on the size of the net). • May include stomach content analysis of sampled commercially important fish.

Methodology for Analyzing data	• ANOVA on numbers of individuals, size and weight distribution; multivariate analysis of catch/community composition, multidimensional scaling, cluster analysis. • Prey items from stomach content identified to lowest taxonomic level, counted and weighed.
Frequency and Duration	• Collect 2 years of baseline data in pre-construction period (surveys at least 4 times per year both years).
Spatial Scale	• Conduct random stratified surveys selected from the following stratification: 10 sites within .5 km of renewable energy site; 10 sites between .5-2.5 km of renewable energy site; 10 control sites (at greater than 2.5 km from site), habitat type, and depth. • Control sites should be selected from areas with similar bathymetry and bottom type to the area of potential effect. • Conduct a minimum of 30 trawls per survey period.
Other Considerations (e.g. Advantages or Disadvantages)	• Not all survey types and gear types will be appropriate to each location. The gear and survey types should be selected based on the issues of greatest concern. • Trawl survey will sample mostly demersal species rather than pelagic species. This survey will be limited to those species most prone to be caught in the net, and will under-sample some species, e.g., lobsters and crabs. • The commercial fishing industry should be consulted on the type of gear used. • The commercial fishing industry should be involved in data collection and survey design when feasible, including the selection of trawl stations. • Accounts for seasonal and annual variability.
Data Elements	• Total individuals/area; • Total biomass/area; • Number of individuals per species and area; • Biomass per species and area; • Diversity,; Length frequency distribution of dominant species; • Time series; and • Spatial data should be submitted in accordance with the Spatial Data Submission Guidelines found on BOEM’s Offshore Renewable Energy Program website.
Data Output	Catch per unit effort (CPUE) for total catch and on a species level; community dynamics.

Table 2b. Recommended ventless trap survey protocols (from BOEM 2013).

Focus	Baseline distribution and abundance of lobster/crab species or some fish species in the in the area of potential effect resulting from activities in a SAP, COP, or GAP.
Methodology	Fixed Gear Survey with Ventless Traps
Description of Methodology	• Use BACI design principles to establish multiple control locations. • Conduct surveys in spring and fall. • Select control locations to have similar bottom types and benthic habitat as project area trawl locations (if conducted). • Sample weight and length of species.
Methodology for Analyzing data	ANOVA on numbers of individuals, size and weight distribution; multivariate analysis of catch/community composition.
Frequency and Duration	2 years of baseline data in pre-construction period (seasonal surveys 4 times per year both years).
Spatial Scale	• Traps set within proposed footprint of renewable energy installation, and at random stratified sites at varying distances from the renewable energy site within and outside of the APE (e.g., 1 km, 10 km, and 25 km). Initial stratification should be based upon habitat type and depth.
Other Considerations (e.g., Advantages or Disadvantages)	• Not all survey types and gear types will be appropriate for each location. The gear and survey types should be selected based on the issues of greatest concern. • The gear and techniques used by the commercial fishing industry should be mirrored in the survey design when sampling commercially-important fish species. • The commercial fishing industry should be involved in data collection and survey design when feasible. • While ventless trap surveys are often used for crustaceans, they may be useful for species such as black sea bass, rock fish, or other species that are attracted to structures and can be caught by traps or pots. • Accounts for seasonal and annual variability.
Data Elements	• Total individuals/area; • Total biomass/area; • # Individuals per species and area; • Biomass per species and area; • Length frequency distribution of dominant species; • Catch per Unit Effort (CPUE) at species level; and • Spatial data should be submitted in accordance with the Spatial Data Submission Guidelines found on BOEM's Offshore Renewable Energy Program website.
Data Output	Catch per Unit Effort (CPUE) at species level.

Scientific Best Practices

McCann (2012) identified potential impacts to fish and fishing from offshore wind development and recommended survey protocols to detect the identified impacts. In addition to the loss of access to fishing grounds, potential effects include contaminant spills, noise, electromagnetic fields, alteration of ecological community composition, decreased fishery efficiency, and changes in species distribution. Malek et al. (2014) surveyed abundance, biomass of the demersal fish and invertebrate community in areas adjacent to the Vineyard Wind lease area and reported species assemblages including a combination of piscivores (silver hake, summer flounder, spiny dogfish), benthivores (American lobster, black sea bass, skates, scup) and planktivores (sea scallop). A literature review on effects of offshore wind development is provided in Appendix C.

BOEM (2013) guidelines recommend a Before-After-Control-Impact sampling design (Green 1979, Stewart-Oaten et al. 1986). The BACI sampling design involves measurement of a response variable (e.g., density of a species) that is expected to be affected by an anthropogenic activity, before and after the intervention, in comparison to one or more control sites that are not expected to be affected in the same manner. BACI is particularly useful for assessing large-scale, unreplicated events (Schwarz 2013, Walters and Holling, 1990).

The series of pre-construction, construction, operation and deconstruction for the Vineyard Wind development will require several periods of sampling, possibly multiple control sites for different species, and a 'beyond-BACI' sampling design with multiple impact periods and control sites (Underwood 1991, 1992). Considering that there are multiple adjacent wind energy leases that are developing on different schedules, evaluating regional impact may also require a 'staircase' design in which impacts are tested at different times on the different impact areas (Walters et al. 1988).

BACI designs and associated extensions have been successfully applied to monitoring impacts of offshore wind farms on fishery resources. Wilber et al. (2018) recognized that impact assessments based on BACI and highly variable fish abundance data can have low statistical power for detecting impacts. So, they supplemented information on relative abundance from a trawl survey, Wilber et al. (2018) monitored fish condition and size distribution to detect impacts of the Block Island Wind Farm on several flatfish species. Although BACI designs are intended to detect negative effects of offshore wind energy developments, analytical designs should be 'two-tailed' to allow for potential positive effects, as observed for European lobsters in a UK wind farm (Roach et al. 2018).

Currently Available Monitoring Data

Oceanographic Surveys

Vineyard Wind developed a water quality study plan to characterize the water quality within and adjacent to the Vineyard Wind Project Area, including dissolved oxygen, chlorophyll, nutrient content, upwelling conditions, and presence of contaminants in water or sediment:

- Existing information was collected near the northwestern boundary of the MA Wind Energy Area for the RI Ocean SAMP (Ullman and Codiga 2010).
- The Northeast Ocean Data Portal provides information about ocean temperature, chlorophyll levels, sediment stability, and currents from a variety of sources, including studies conducted by SMAST, Woods Hole Oceanographic Institute (WHOI), and The Nature Conservancy (TNC).

- The National Coastal Conditions Assessment (NCCA) provides information about the biological and physical conditions of United States coastal waters and Great Lakes. These data are collected using standardized protocols to allow for comparison of various metrics, including water quality, sediment quality, ecological contamination, and benthic community composition, between geographic areas. Surveys conducted along the Atlantic coast of the US, from Maine to Virginia, involved sampling at 283 sites, covering approximately 10,700 mi^2 of water. The 2010 report is the most recent synthesis of NCCA data.
- The Northeast Fisheries Science Center (NEFSC) completes fisheries-independent trawl surveys from the Scotian shelf to Cape Hatteras each spring and fall. This survey is performed each spring and fall using standardized sampling procedures and includes the collection of water temperature and salinity data at each trawl location since 1999. These surveys will be valuable for providing pre-construction information on inter-annual variability in the lease area. However, NEFSC has determined that the survey cannot be conducted in the turbine field during and after construction. Therefore, supplemental surveys will be needed for impact analysis.
- NOAA data buoy 44097 is located approximately 12 NM to the west of the southern corner of the Vineyard Wind lease area and has been collecting data since 2009. This buoy is anchored in 48 m of water and records information about sea surface temperature (measured at 0.46 m below the water line), wave height, dominant wave period, average wave period, and mean wave direction.
- The World Ocean Database (WOD), managed by NOAA's National Oceanographic Data Center, is the world's largest collection of internationally-available vertical profile data of ocean characteristics. The WOD includes quality-controlled data on a variety of physical, chemical and biological parameters collected from instrumentation on ships, moored buoys, drifting floats, and numerous offshore structures. Salinity and temperature data collected from within the Vineyard Wind Lease Area are available.
- The Martha's Vineyard Coastal Observatory (MVCO) is located near South Beach in Edgartown, MA and is run by WHOI. This observatory collects environmental and meteorological data using a variety of instruments, including a subsurface node located approximately 1.5 km south of Edgartown Great Pond in 12 m deep water. Instrumentation on this node records temperature, salinity, waves, and currents (MVCO 2017). These data represent conditions shallower than those found within the Vineyard Wind Project Area and not directly relevant.

Benthic Surveys

Vineyard Wind developed a Benthic Resources Study Plan to characterize the benthic resource. Data sources are available to characterize benthic resources within and adjacent to the Vineyard Wind Project Area. Existing data support characterization of abundance, diversity, and percent cover of benthic macrofauna and macroflora, and include multivariate analyses of community composition, both within the Project Area and surrounding area. The existing datasets consist of a mix of grab and imagery data collected within the Project Area, covering both spring and fall seasons, over a two-year period, which will enable characterization of seasonal and inter-annual variability. The spacing of the existing data within the Project Area varies between approximately 5-7 km. Based on preliminary review of the datasets, little variation in substrate type and relatively low animal diversity was observed throughout the Project Area.

BOEM Revised Environmental Assessment (BOEM 2014) provides general information about the benthic habitat within the MA Wind Energy Area and references numerous sources that provide more detailed data about the region. The general benthic habitat type found within the MA Wind Energy Area is characterized by fine- and medium-grained sand, and the organism assemblage includes amphipods and other crustaceans, polychaetes, bivalves, sand dollars, burrowing anemones, and sea cucumbers. These organisms are important food sources for many commercially important northern groundfish species. No state-managed artificial reefs are located within the MA Wind Energy Area (though shipwrecks and other objects provide artificial reef habitat, see Archaeological Resources study plan).

SMAST Benthic Survey Pyramid Study (SMAST 2016, Appendix A) collected still and video images of the seafloor using a survey pyramid. Images of the seafloor from surveys conducted in 2012 included the MA Wind Energy Area and surrounding areas. Four replicate images were taken at each sampling location. The results from this survey indicated that higher resolution sampling than 5.6 km between stations would be needed to provide enough baseline data to support a comprehensive BACI study of benthic animals or to assess if a lease area is providing a "reef" or "sanctuary" effect. SMAST surveys also provided data relating to the average presence or abundance of selected benthic organisms (sand dollar, bryozoans or hydrozoans, sponges, scallops, sea star, crab, hermit crab, moon snail, flat fish, red hake, and skate) within each cell from the New England Fishery Management Council Swept Area Seabed Impact (SASI) model from 2003 to 2012. SMAST surveys provided data relating to the presence or abundance of selected benthic organisms, including sand dollar, bryozoans or hydrozoans, sponges, scallops, sea star, crab, hermit crab, moon snail, flat fish, red hake, and skate. The Northeast Ocean Data Portal presents invertebrate abundance data collected during the SMAST video surveys from 2003 to 2012. These data products indicate that hermit crabs, moon snails, and sea stars are uncommon in the Lease Area; average abundance values for these species were approximately 0 individuals per sample (values in the 16th or lower percentile of all sampled areas) or lower less than the 16th percentile. Hydrozoans, bryozoans, and sponges were also uncommon in the area; these organisms were observed in less than 25% of samples in the region. Sand dollars were abundant in the Lease Area and occurred in up to 75-100% of samples in the northern portion of the Lease Area.

Benthic Macroinvertebrate Sample Analysis Report (ESS 2016) includes four benthic samples within the Lease Area during SAP survey activities in the fall of 2016. ESS Group analyzed the benthic samples for macroinvertebrate taxa richness and density, and benthic community composition. Measures of benthic macrofaunal diversity, abundance, and community composition were recorded to describe the existing condition of benthic resources within the Project Area. The examined samples include 32 identified taxa. Taxa richness per sample ranged from 6 taxa to 19 taxa per grab, with a mean taxa richness of 15 taxa per grab. The mean macrofaunal density for the analyzed samples was 118,370 individuals/m3. The highest macrofaunal density (234,409 individuals/m^3) was found in Grab 4, while macrofaunal density was lowest (48,227 individuals/m^3) in Grab 2. Of the four samples analyzed, three were characterized by densities of 90,000 individuals/m^3 or more. The benthic macrofaunal assemblage in the analyzed samples consisted of polychaete worms, crustaceans, mollusks, echinoderms, nematode roundworms, and nemertean ribbon worms. The most speciose taxonomic group was polychaete worms, which contributed approximately 45% of the taxa documented in the analyzed samples. The taxonomic group with the highest density was polychaete worms, followed by nematode roundworms and crustaceans. The most abundant taxa observed were nematode roundworms (Nematoda), the lumbrinerid polychaete *Scoletoma* sp., and a paraonid polychaete (Paraonidae). Together, these taxa accounted for more than 50% of all individuals identified in this study.

CZM (2012) details the results of infaunal sampling conducted during the MA Coastal Zone Management survey in September 2011. This survey included benthic grabs at a total of 214 stations, 95 of which were located south of Cape Cod and the islands, in the vicinity of the Vineyard Wind Project Area. The 20 most abundant taxa, in samples collected from south of the islands, comprised 94.2% of all individuals collected. These taxa included polychaetes (11 taxa), amphipods (three taxa), bivalves (two taxa), echinoderms (one taxa), nemerteans (one taxa), oligochaetes (one taxa), and tanaids (one taxa). The most abundant taxon was the bivalve family Nuculidae, which comprised over 24% of all organisms. Capitellid polychaetes and Ampeliscid amphipods were also abundant, comprising 16.0% and 9.0% or organisms, respectively. Multivariate approaches including cluster analysis, SIMPER, ANOSIM, and NMDS were used to analyze benthic assemblages and test the hypothesis that community composition differed with depth and sediment type. These analyses did not reveal significant differences in assemblages between depths and sediment types.

Annual Report of a Comprehensive Assessment of Marine Mammal, Marine Turtle, and Seabird Abundance and Spatial Distribution in US Waters of the Western North Atlantic Ocean was a shipboard survey focused on sea birds, cetaceans, and sea turtles, but also sought to document the relationships between the abundance of these organisms and the biological and physical environment. So, benthic samples were obtained from five different BOEM Wind Energy Areas, including the MA Area. Benthic grab samples were analyzed to identify benthic infaunal and epifaunal assemblages, as well as sediment textures. All benthic data were processed and are maintained at the NEFSC J.J. Howard Lab in Sandy Hook, NJ.

Fishery Physical Habitat and Epibenthic Invertebrate Baseline Data Collection is an on-going study that was designed to assess and characterize benthic habitat and the epibenthic macroinvertebrate community in existing and proposed Wind Energy Areas from Massachusetts to North Carolina via multibeam sonar, and optical (still and video) imaging of the seafloor. Although this study is currently ongoing, data from the study are available and will be incorporated into the evaluation of benthic resources for the Vineyard Wind Project Area.

Although analysis and reporting is on-going for some studies, there is adequate data to determine the abundance, diversity, percent cover, and community composition of benthic resources, as well as understand any season and inter-annual trends in the community, within the offshore Project Area. Additional benthic data collection during G&G surveys has been used to supplement the existing data to adequately characterize the benthic resources within the export cable route. Furthermore, a benthic monitoring plan (pre- and post- construction) has been developed as part of the project mitigation in support of NEPA, which will establish a repeatable sampling protocol including control sites outside the area of projected seafloor impacts.

Fish and Invertebrate Trawl Surveys

Vineyard Wind developed a Fisheries and Essential Fish Habitat Study Plan to characterize these resources. Many recently completed studies, as well as data from long term monitoring programs, are available that provide information about fisheries within the MA Wind Energy Area and surrounding southern New England waters. The most relevant data sources are the Northeast Fisheries Science

Center multispecies bottom trawl surveys, the Massachusetts Department of Marine Fisheries Trawl surveys, the Northeast Ocean Data Portal, and the BOEM EA. Existing data support characterization of distribution, abundance, and composition of fish species within the area potentially effected by project activities. These data will support inter-annual and seasonal characterization of the fish species present within and adjacent to the Project Area. For those species with potential EFH designated for at least one life stage within the Project Area; habitat characteristics and preferences will be reviewed and compared to determine the potential for impact to these species due to project activities.

The BOEM Environmental Assessment (2014) provides a baseline characterization of the fisheries and essential fish habitats (EFH) in the MA Wind Energy Area compiled from various sources. This characterization includes information about commercially important and/or protected finfish and invertebrates. Fishery Physical Habitat and Epibenthic Invertebrate Baseline Data Collection (BOEM & NOAA NEFSC) established baseline benthic habitat characteristics and presence of macrofaunal species in existing and proposed Wind Energy Areas from Massachusetts to North Carolina via multibeam sonar, and optical (still and video) imaging of the seafloor. Although this study is currently ongoing, data from the study are available and will be incorporated into the evaluation of fish resources for the Vineyard Wind Project Area. The finfish assemblage found within the MA Wind Energy Area is characterized by intermediate and shallow finfish assemblages defined by Overholtz and Tyler (1985), and several federally managed demersal and pelagic fishes (e.g. winter flounder, yellowtail flounder, monkfish, Atlantic herring, Atlantic bluefin tuna, yellowfin tuna, king mackerel, and whiting). Several fish species with EFH designations for one or more life stages also potentially occur within the Wind Energy Area, though there are no habitat areas of particular concern (HAPC) within this region. Though lobster landings in southern New England (SNE) are low compared to Gulf of Maine catches, the Wind Energy Area does contain important lobster fishing grounds for the SNE stock area.

The Northeast Fisheries Science Center (NEFSC) completes fisheries-independent trawl surveys from the Scotian shelf to Cape Hatteras each spring and fall, including the area proposed for project activities. This survey has been performed yearly since 1968 using standardized sampling procedures. Data from trawl surveys conducted within and in the vicinity of the Vineyard Wind Project Area were requested from NEFSC. These data provide a long-term, comprehensive characterization of abundance, distribution and temporal occurrence of species collected by trawl gear. Data from trawls conducted within the MA Wind Energy Area and adjacent waters from 1948-2016 were received from NFSC and are currently undergoing analysis. Although this survey was primarily designed to sample demersal species, demersal species are also likely to experience the greatest potential negative impact from project activities, compared to pelagic species. (i.e. short-term noise due to pile driving vs. permanent alteration of seafloor due to installation of foundations). Preliminary results indicate seasonal variability in finfish abundance, though several species, including Atlantic herring, butterfish, spiny dogfish, and silver hake, are common within the area throughout the year.

The Massachusetts Division of Marine Fisheries conducts trawl surveys every spring and fall throughout coastal MA waters. Though these surveys do not include the MA Wind Energy Area, they provide valuable information about regional fish abundance and habitat use. These data will also be directly relevant when evaluating potential effects of the submarine transmission cable, which will pass through the trawl survey area. The MA DMF trawl surveys include Nantucket Sound and Muskeget Channel through which the submarine cable will pass and provide information about seasonal and inter-annual variability in nearshore fish abundance. Species that occurred in greater than 30% of all spring trawls in

Regions 1 and 2 from 1978-2019include winter flounder, windowpane, little skate, northern sea robin, winter skate, summer flounder, scup, and black sea bass. The most commonly observed finfish in fall trawls include butterfish and smooth dogfish, in addition to the above species.

Northeast Ocean Data Portal's Marine-Life Data and Analysis Team (Fogarty and Perretti 2016, MDAT 2016), in collaboration with the Northeast Regional Planning Body and expert work groups, composed of over 80 regional scientists and managers, produced a series of data products presented on the Northeast Ocean Data Portal (Fogarty and Perretti 2016, MDAT 2016). Data from the NEFSC, the state of Massachusetts Division of Marine Fisheries (MDMF) trawl, the states of Maine and New Hampshire (ME/NH) trawl and the North East Area Monitoring and Assessment Program (NEAMAP) trawl are illustrated in different data layers. For detailed survey methodologies and details, please refer to: http://www.northeastoceandata.org/. This resource displays the biomass of 82 different fish species and groups observed during NEFSC and MA DMF trawl surveys in the Western North Atlantic, which includes the MA WEA and adjacent waters. Results indicate that the Project Area does not support a large biomass of diadromous fish species.

Southern New England Juvenile Fish Habitat Research (CFF 2016), funded by BOEM, seeks to identify if monkfish, winter, windowpane, and yellowtail flounder exhibit seasonal differences in abundance within and around the MA and RIMA Wind Energy Areas. This study will also provide maps of habitat types using data collected via video surveys and identify the habitat preferences of the above listed flatfish. This research will incorporate data from the NEFSC multispecies spring and fall bottom trawls, as well as winter dredge surveys conducted by CFF. This study is on-going and results have not yet been published. If data are available in time, they will be incorporated into the COP analysis.

Additional studies that contribute to the available fisheries information in the region of southern New England include:

- Southern New England Industry-Based Yellowtail Flounder Survey (2003-2005)
- Northeast Area Monitoring and Assessment Program (NEAMAP)

Multiple surveys and studies encompassing numerous survey methodologies (trawls and video surveys) provide comprehensive data sets to sufficiently define the spatial and temporal distribution of fishery resources and to assess potential impacts to these species within the Vineyard Wind Project Area. The compilation of the data sources described above provide adequate information on fishery resources in and adjacent to the Project Area.

Avian Surveys

Vineyard Wind developed a coastal and marine birds and bats study plan to define their spatial and temporal distribution within the Vineyard Wind Project Area. In its Construction and Operations Plan (COP), Vineyard Wind described avian presence in the Project area, defined their spatial and temporal distribution, and assessed potential impacts of Project activities on these species. The three most recent and comprehensive data sources are the Abundance and Distribution of Seabirds off Southeastern Massachusetts (Veit et al. 2016), the Kinlan et al. (2016) modeling study (available on the Northeast Ocean Data Portal), and the data synthesis that has been summarized in BOEM's 2014 Environmental Assessment (EA) for the Massachusetts Wind Energy Area (BOEM 2014).

Veit et al. (2016) provides data on abundance and distribution of seabirds off southeastern Massachusetts, 2011-2015, to inform renewable energy activities in the MA Wind Energy Area by quantifying the distribution and abundance of seabirds in the region. This study conducted repeated surveys over time and sought to identify hotspots of greater than average bird density. These surveys encompassed an area of approximately 3300 km^2, and included the MA Wind Energy Area and two much smaller areas closer to Nantucket and Martha's Vineyard. A total of 38 aerial surveys, covering approximately 23,000 linear km of transect, were conducted between November 22, 2011 and January 14, 2015. A total of 25 bird species were observed during these surveys. Two hotspots of increased bird activity were identified, one in the Muskeget Channel area, and another near the western edge of Nantucket Shoals. The Muskeget Channel hotspot was generally characterized by high densities of common eiders, black scooters, long-tailed ducks, common and red-throated loons, and common and roseate terns, whereas high densities of long-tailed ducks, white-winged scooters, and common and roseate terns were observed on Nantucket Shoals. This report provides detailed maps showing the distribution of individual species within the MA Wind Energy Area in each season. Hot spot avian activity was not observed in the project area.

The Marine-Life Data and Analysis Team of the Northeast Ocean Data Portal, in collaboration with the Northeast Regional Planning Body and expert work groups composed of over 80 regional scientists and managers, produced a series of data products presented on the Northeast Ocean Data Portal (Kinlan et al. 2016, MDAT 2016). This resource provides modeled estimates of the predicted distribution and abundance of 151 different marine mammal, bird, and fish species in the Western North Atlantic. This data product is the summation of 23 years of surveys, conducted along nearly 1.1 million linear km of line-transects, under varying survey methodologies. For detailed survey methodologies , please refer to: http://www.northeastoceandata.org/. The results of the study conducted by the Marine-Life Data and Analysis Team are represented within an online mapping tool; which enables extensive assessment of 26 species and numerous multi-species guilds, on a monthly basis, and over a user defined geographic range, which includes the entirety of the Project Area and adjacent waters.

BOEM (2014) provides a baseline characterization of the coastal and marine bird and bats in the MA Wind Energy Area compiled from various sources. Over 450 species of birds could possibly use the onshore and offshore areas of Massachusetts, though many of these species are rare and unlikely to occur in offshore areas (Blodget 2007). The bird species most likely to be found within the Wind Energy Area include 19 species of waterfowl, 4 species of loons and grebes, 10 species of shearwaters and petrels, 3 species of gannets and cormorants, 2 shorebirds, 3 jaegers, 6 alcids, 3 sulids, and 20 species of gulls and terns (eBird, 2014). Sea ducks including the Long-tailed duck winter in the Wind Energy Area and surrounding areas and especially large population of these species may be observed from November through March (Allison et al., 2006; Allison et al., 2009). One ESA-listed endangered bird species and two threatened species may occur within the Wind Energy Area; the roseate tern and the piping plover and red knot, respectively. The roseate tern is not expected to be present in the Wind Energy Area during breeding and post-breeding staging periods (Kinlan et al., 2014). However, the migratory patterns of this species are not well known, and the roseate tern may traverse the Wind Energy Area in both spring and fall. Piping plovers are restricted to sandy beach habitats during the breeding season (mid-May through August) and so are expected to occur sporadically in the Wind Energy Area only during migratory periods (Burger et al., 2011; Normandeau Associates Inc., 2011). The red knot breeds far to the north and winters far to the south of the MA Wind Energy Area, and so is only likely to possibly traverse this area during spring and fall migrations. Research suggests that red knot migration through the Wind Energy Area occurs more often during the fall than during the spring due to migratory route variations (Burger et al., 2012b; Niles et al., 2010; Normandeau Associates Inc., 2011).

Additional studies that contribute to the available information in the Lease Area related to coastal and marine birds and bats include:

- Aerial Surveys for Roseate and Common Terns South of Tuckernuck and Muskeget Islands July-September 2013 (Veit et al. 2014)
- Compendium of Avian Occurrence information for The Continental Shelf Waters Along the Atlantic Coast of The United States: Final Report (O'Connell et al. 2011)
- Information Synthesis on the Potential for Bat Interactions with Offshore Wind Facilities – Final Report (Pelletier et al. 2013)
- Pelagic Seabirds off the East Coast of the United States 2008-2013 (Veit et al. 2015)
- The Relative Vulnerability of Migratory Bird Species to Offshore Wind Energy Projects on the Atlantic Outer Continental Shelf (Robinson et al. 2013)

Marine Mammal and Sea Turtle Surveys

Vineyard Wind developed a Marine Mammal and Sea Turtle Study Plan for an analysis of the sightings data relevant to the Vineyard Wind Project Area. Multiple surveys and studies that have been conducted encompass numerous survey methodologies (aerial, boat, acoustic) that provide comprehensive data sets that sufficiently define their spatial and temporal distribution and are more than adequate to assess the potential impacts to these species within the Vineyard Wind Project Area. The two most recent and comprehensive data sources are the Northeast Large Pelagic Surveys (NLPS) and the Roberts et al. and MDAT (2016) modeling study (available on the Northeast Ocean Data Portal), which will be the primary basis of MM&ST data for this project. Six species of large and medium whales were sighted including North Atlantic right whale, humpback whale, fin whale, sei whale, minke whale, and sperm whale. Sightings occurred year-round with peak abundance occurring in spring and summer and the lowest abundance occurring in autumn. The North Atlantic right whale peak abundance occurred during the winter. Small cetaceans were not the focal species of the study; and therefore, resulted in a large number of "unidentified dolphins". The most commonly identified species included short-beaked common dolphin, bottlenose dolphin and harbor porpoise. Sightings occurred year-round with peak abundance occurring in summer and autumn and the lowest abundance occurring in spring. Three species of sea turtles were sighted including leatherback sea turtle, loggerhead sea turtle, and Kemp's Ridley sea turtle. Sighting occurred during the spring, summer, and autumn with the peak abundance occurring in summer and autumn. No sea turtles were sighted during winter.

The collaborative aerial and acoustic surveys for large whales and sea turtles were conducted for the MassCEC and BOEM by the Large Pelagic Survey Collaborative (comprised of the New England Aquarium, Cornell University's Bioacoustics Research Program, the University of Rhode Island and the Center for Coastal Studies) (Kraus et al. 2016). This study was designed to provide a comprehensive baseline characterization of the abundance, distribution, and temporal occurrence of MM&ST, with a focus on large endangered whales and sea turtles, in the RI/MA and MA Wind Energy Areas and surrounding waters. Information was collected using line-transect aerial surveys and passive acoustic monitoring from October 2011 to June 2015 in the MA Wind Energy Area, and from December 2012 to

June 2015 in the RI/MA Wind Energy Area. A total of 76 aerial surveys were conducted, and Marine Autonomous Recording Units (MARUs) were deployed for a total of 1,010 calendar days, during the study period. For detailed survey methodologies and results, please refer to: https://www.boem.gov/RI-MA-Whales-Turtles/.

The Northeast Ocean Data Portal's Marine-Life Data and Analysis Team, in collaboration with the Northeast Regional Planning Body and expert work groups composed of over 80 regional scientists and managers, produced a series of data products presented on the Northeast Ocean Data Portal (Roberts et al. 2016, MDAT 2016). This resource provides modeled estimates of the predicted distribution and abundance of 151 different marine mammal, bird, and fish species in the Western North Atlantic. The results of the study are represented within an online mapping tool; and therefore, assessments can be conducted for 26 species and numerous multi-species guilds, on a monthly basis, and over a user defined geographic range, which includes the entirety of the Lease Area and adjacent waters. Results of this study can also help to illustrate not only what is occurring in specific waters, but also identify population dynamics and migratory movements along the entire coast to help predict population level trends. This data product is the summation of 23 years of surveys, conducted along nearly 1.1 million linear km of line-transects, under varying survey methodologies. For detailed survey methodologies and details, please refer to: http://www.northeastoceandata.org/.

Additional studies that contribute to the available information in the Lease Area related to MM&ST include:

- NMFS Stock Assessments (Waring et al. 2016)
- North Atlantic Right Whale Consortium (Pettis et al. 2016)
- Atlantic Marine Assessment Program for Protected Species (NOAA 2015)
- Literature Search and Data Synthesis for MM&ST in the U.S. Atlantic from Maine to the Florida Keys (Waring et al. 2012)
- Rhode Island Ocean Special Area Management Plan (RI CRMC 2013)

3. Workshops with Fishermen

Fishermen were invited to four workshops to identify what questions and information would be most valuable for pre- and post-construction assessments of fisheries, ecological conditions, social and economic aspects of fisheries in and around the Vineyard Wind offshore wind lease area:

- Thursday November 8, School for Marine Science & Technology (836 South Rodney French Boulevard, New Bedford MA)
- Thursday November 15, Commercial Fisheries Center of Rhode Island (East Farm Campus Building 61B URI, Kingston RI)
- Monday November 19, 6-8pm, Chatham Community Center (702 Main Street, Chatham MA)
- Monday December 3, West Tisbury Library (1042 State Rd, West Tisbury MA)

Individual fishermen and fishing organizations, representing all active fisheries in the Vineyard Wind lease area were contacted in person, by phone and by email. Workshops included a brief description, status and plans of the Vineyard Wind project, an explanation of impact monitoring and BACI sampling designs, results from some initial fishery resource surveys, and discussion to identify priorities for pre-and post-construction monitoring plans. Vineyard Wind recognized that the time invested in meetings is time taken away from fishing and offered commercial fishermen $200 to attend workshops.

Over 100 people attended workshops, including 63 commercial fishermen, several recreational fishermen, and fishery scientists. The primary information solicited from fishermen was a list of important target species in their fisheries (Table 3). In addition to information on target species, fishermen testified that they were equally concerned with impacts from construction, turbines and cables. They were also concerned with broader ecosystem impacts, including nontarget species (right whales, sea turtles, sharks, sea birds, plankton), benthic habitats and system productivity.

More practically, fishermen offered suggestions on implementing a monitoring plan. They recommended that field sampling should be conducted in collaboration with active fishermen who have expertise in survey gear, target species and fishing in the lease area. Fishermen recommended that improving commercial and recreational fishery monitoring data would also help to detect impacts. Workshop participants also suggested a that a Fishermen’s Monitoring Working Group should be involved in the implementation of the monitoring plan.

Table 3. Target species in commercial and recreational fisheries in the Vineyard Wind lease area, as identified by workshop participants.

Species	New Bedford	Rhode Island	Chatham	Marthas Vineyard
Lobster	X	X	X	X
Monkfish	X	X	X	X
Squid	X	X	X	X
Fluke	X		X	X
Jonah crab	X	X		X
Scallop	X		X	X
Tuna	X	X		X
Black sea bass	X			X
Cod	X			X
Conch	X			X
Scup	X			X
Sharks	X	X		
Skate	X	X		
Surf clam	X	X		
Winter flounder			X	X
Yellowtail flounder			X	X
Butterfish				X
Haddock				X
Herring	X			
Horseshoe crab			X	
Mackerel	X			
Mahi mahi		X		
Ocean quahog	X			
River herring			X	
Striped bass				X
Swordfish		X		
Whiting	X			

4. Meetings with Regulators

Scientists from state agencies (MA and RI) and federal agencies (NOAA and BOEM) were invited to two meetings in New Bedford MA (December 18 2018 and February 14 2019) to present results from fishermen workshops as well as draft recommendations for the monitoring plan. Requirements and technical guidance from BOEM (2013), MADMF (2018) and RICRMC (2010) were reviewed as well as best practices in impact monitoring.

The first meeting included a presentation on impact monitoring and BACI sampling designs, results from some initial fishery resource surveys, and a summary of stakeholder feedback from fishermen's workshops (e.g., concerns about impacts from construction, turbines and cables; nontarget species; improving commercial and recreational fishery monitoring data; preference for sampling with fishermen who have local expertise in the fishery; a Fishermen's Monitoring Working Group). The discussion included:

- The group suggested that defining the objective of the monitoring plan and the questions that it can answer would help to develop an appropriate sampling and analytical design.
- The challenge posed by the different development schedules of each lease area for detecting local or regional impacts was recognized. Multiple development periods, multiple impact areas and multiple control areas were suggested in a "beyond BACI" design (Underwood 1991, 1992). The 'staircase' design (Walters et al. 1988) was proposed as an appropriate approach to regional analysis.
- Another challenge identified was that the construction schedule does not allow sufficient time for pre-construction monitoring to represent inter-annual variability of some resources (e.g., squid). One approach that was discussed is to match monitoring protocols to those of existing surveys so that they can be used for baseline information.
- The power analysis was discussed to clarify that, based on the general magnitude and variability of trawl catches in the preliminary survey, approximately 20 trawl stations would be needed in each area (control and impact) to detect a substantial change in density of any of the target species.
- A recommendation was made to consider stratification by sediment and depth to improve impact monitoring design. However, the group recognized that the Vineyard Wind lease area has relatively consistent substrate and only a slight depth gradient. By contrast, other Wind Development Areas, like the area on and adjacent to Cox Ledge may require stratification.
- If a trawl survey is not feasible in the turbine field, as NEFSC has determined for their trawl survey, the group recommended that a beam trawl survey may be an option for monitoring benthic and demersal species.
- Although most of the focus was on monitoring local density using resource surveys, the need to monitor changes in distribution will require ancillary field work (e.g., tagging) and analysis (e.g., larval dispersal).
- The group also suggested that the potential reef effect of turbines should be considered in local and regional impact analysis.
- The group recognized that fishery monitoring data may be the best approach to detecting impacts on highly migratory species. However, logbooks from commercial and for-hire recreational fishermen do not have the spatial resolution needed to evaluate local impacts, and alternative

monitoring (at-sea observers, electronic logbook, electronic monitoring) would be needed to use fishery monitoring data in the impact analysis.

- Fishermen's concerns about electromagnetic fields near the cables was discussed. Several people suggested that sheaths burying cables is considered to be the best way to insulate electromagnetic fields, and the monitoring plan should ensure that burial is maintained, particularly in high energy environments, like Muskeget Channel.
- In response to a question about data usage, the primary application of the data would be to detect impacts by a monitoring group that meets annually to develop an annual report, but data may also have other applications.

The second meeting included a presentation of the main elements of the monitoring recommendations. Several refinements to the plan were suggested, including approaches to coordinate the monitoring plan with other monitoring plans and other surveys so that the regional impact evaluations can be modular and nested. For example, trawl mensuration was suggested to standardize area swept among surveys and facilitate comparability among other monitoring plans and other surveys. A recommendation for Gradient analysis was also identified as an option for detecting regional impacts. Fixed optic surveys were suggested to monitor ecological succession on and around turbines. For some hard-bottom habitats, multiple finfish sampling gears (e.g., mobile trawls on soft bottom and fixed gillnets or longlines on hard bottoms) may be needed. Sidescan sonar was also identified as a way to monitor cable burial. NEFSC submitted some comments after the meeting (Appendix D).

5. Recommendations

Based on the input from stakeholders, state and federal guidelines, existing and other ongoing surveys, as well as best practices in environmental monitoring, we recommend a monitoring plan for the proposed Vineyard Wind development that is based several monitoring surveys and supplemental studies. The recommended surveys are expected to provide data that can be compared to previous data and ongoing regional studies to support a regional, longer-term study program to monitor the regional impacts of offshore wind development on fishery resources.

<u>Questions and Hypotheses</u> - According to state and federal requirements, the monitoring plan should detect impacts of the proposed construction and operation of the wind farm, including the turbine field and cable route, on fishery resources. The primary question that should be addressed is "Do the construction or operation of the Wind Farm affect the local density of target fisheries species in the development area?" This question can be posed as a testable hypothesis, with a null hypothesis of equal mean density of each species in each treatment (before, during construction, after construction, control, impact) and significant impact being detected by a significant time-area interaction effect using a factorial analysis (e.g., a generalized linear model with mean density of each species as the response variables, with time, area and time-area interaction effects).

Sampling should be at randomly selected locations within each area. If randomly sampled monitoring data indicate that there are persistent patterns of heterogeneity in response variables within impact and control areas, further stratification may be needed for an efficient sampling design. A priori stratification that does not reflect persistent patterns in species density would decrease the efficiency of the survey for detecting impacts. In the Vineyard Wind lease area, there is a slight depth gradient, but the benthic substrate is relatively homogeneous, and there is no apparent need for stratification within treatment areas from the available data. By comparison, the proposed impact and control areas are much smaller than NEFSC and NEAMAP trawl survey strata.

As demonstrated by Wilber et al. (2018), abundance data can be supplemented with size frequency samples to answer the question “Do the construction or operation of the Wind Farm affect the local size distribution of target fisheries species in the development area?” This question can also be posed as a testable hypothesis, with a null hypothesis of equal mean size (or size distribution) of each species in each treatment (before, after, control, impact, etc.).

More extensive regional research is needed to answer broader questions, such as determining which aspect of the wind farm is affecting fishery resources, as recommended by MADMF (2018). Our recommendations are focused on monitoring impacts on the local density of fishery resources and are conditional on other ecological impacts being detectable with the currently available monitoring programs and existing studies (described above).

General Sampling Design - In order to comply with state and federal guidelines, as well as best practices in environmental impact monitoring, sampling will need to be conducted before, during and after construction in impact and control areas to support a ‘beyond BACI’ analysis (e.g., sampling at multiple control sites at multiple periods before and after impact; Underwood 1991, 1992). BACI analysis and its extensions involve factorial statistical designs in which impacts are determined by significant interaction effects, typically tested using a generalized linear model (BOEM 2013). Two major challenges with this approach are the need to represent natural temporal variability in baseline sampling before construction begins and the limited availability of true control areas. Both challenges can be addressed by analyzing monitoring data in the context of regional sampling. Although regional sampling has relatively low spatial resolution (i.e., few observations in the impact area), it offers years of standardized sampling for evaluating inter-annual variability, samples many candidate control areas for different species, and offers regional context for coordinated monitoring of adjacent wind energy lease sites.

Integrated analysis of regional sampling and impact monitoring data will also facilitate the evaluation of regional impacts and will support the request to coordinate monitoring plans among adjacent lease areas. The design of regional impact analysis will be more complex because of the different schedules of lease site developments and the resulting sequential impacts. Therefore, regional impact analysis will require a ‘staircase’ design (i.e., including different time period impact treatments; Walters et al. 1988). A further extension would be a gradient analysis (Ter Braak and Prentice 2004). Such analysis will be facilitated by the implementation of comparable protocols among impact monitoring programs and regional sampling (e.g., sampling equipment, seasonality, sample processing).

Surveying each group of taxa over multiple life history stages requires sampling equipment that can efficiently capture multiple species. For example, a trawl survey is needed to monitor several important species of finfish and squid, a benthic survey is needed to monitor demersal invertebrate species, a trap survey is needed to sample mobile invertebrates, and a plankton survey is needed to sample all commercial and recreational target species. As a supplement to such multispecies surveys, field and laboratory research is needed to study regional cumulative impacts, fish distribution, larval dispersal, cable burial, and ecological succession on and near wind turbines.

Monitoring Commercially and Recreationally Targeted Species

Several distinct surveys will be needed to monitor the abundance and distribution of target species that are important to recreational and commercial fishermen. Sampling is required for different life stages and during all four seasons. Some surveys can be coordinated to be sampled at the same locations and dates (e.g., conducting plankton tows in coordination with a trawl survey or an optical survey). For each survey, there would be several advantages to surveying with protocol used for regional sampling to provide more years of baseline samples as well as a regional context for trends in abundance and distribution during wind farm construction and operation.

Trawl Survey for Finfish and Squid

The Northeast Area Monitoring and Assessment Program (NEAMAP) was developed to support stock assessment and fisheries management in the northeast United States (Bonzek et al. 2016). NEAMAP has sampled from Cape Cod to Cape Hatteras since 2006. The net used by NEAMAP (4 seam, 3 bridle, 400 x 12 cm net with a cookie sweep and 1" knotless liner in the cod end) was designed by the Northeast Trawl Advisory Panel (NTAP, www.mafmc.org/ntap), an advisory panel of the Mid-Atlantic and New England Fishery Management Councils composed of Council members, fishing industry, academic, and government and non-government fisheries experts. The net was initially developed for the Northeast Fisheries Science Center's (NEFSC) offshore trawl survey to efficiently sample a wide range of commercially and recreationally important species (Johnson & McCay 2012). The net design also adopted features of the 4-panel nets with high headrope height used by RI fishermen to target squid (see letter from CFCRI in appendix D). The NEFSC offshore survey uses rockhopper footrope to survey hard bottom habitats (e.g., in the Gulf of Maine), but the NEAMAP survey uses a foot rope that is more suited to sampling flatfish and appropriate for the relatively soft bottom in the Vineyard Wind lease area. The smaller vessel used by the NEAMAP inshore survey (F/V Darana R, 80 ft, 166 gross tons, 670 HP) is also much more suitable for sampling near turbines than the much larger vessel used by the offshore NEFSC survey. The NEAMAP trawl survey uses Thyboron Type IV 66" doors.

Both NEAMAP and NEFSC survey data are used in many stock assessments, so the relative efficiency of the two surveys is well estimated for many species. Therefore, we recommend that the monitoring plan should emulate the NEAMAP survey protocol as much as possible to allow comparison with regional NEAMAP and NEFSC trawl survey data. The NEAMAP net, doors and sampling protocol should be used for trawl samples. Net mensuration equipment will be essential for comparing area swept among surveys with different vessels and maintaining the valid tow criteria. Minimally, trawl survey sampling should be conducted in spring and fall, during NEFSC and NEAMAP surveys. The Block Island Wind Farm Demersal Fish Trawl Survey (Inspire 2012, 2018) offers an example of a trawl survey designed to monitor wind farm impacts with a BACI design using the NEAMAP protocol.

Based on the variability in baseline trawl survey samples (Table 4, Figure 1), the optimal sample size for detecting impacts for the primary recreational and commercial target species is approximately 20 tows in each area, in each sampling season. We recommend that initial surveying be conducted with 20 tows in each control and impact area, and the power analysis should be updated with data collected from the final monitoring plan protocol. Sampling 20 tows in the relatively small impact and control areas is much greater spatial density than sampled by NEAMAP or NEFSC trawl surveys. By comparison the Block Island Wind Farm trawl survey has two randomly selected stations per area (Inspire 2018). An Experimental Fishing Permit or Letter of Authorization will be needed for the sampling, but the expected catches from such a survey is a small portion of fishery allocations. For example, extrapolated catches based on NEAMAP swept area (25,000 m^2; Bonzek et al. 2016), 20 tows in each area and baseline catches (Table 1) are approximately 100 kg of winter flounder and 10 kg of yellowtail flounder, two of the most restricted fishery allocations in the area. The catch associated with sampling more than 20 stations may present a conservation concern, a challenge for obtaining an Experimental Fishing Permit, and may itself have substantial negative impact on recreational and commercial target species. A more specific proposal for a trawl survey in the Vineyard Wind lease area is in Appendix G.

Table 4. Sample statistics (number of samples, mean, and standard deviation) from baseline trawl survey sampling in the development and control areas.

Species	Density (kg/km2)								
	Development Area			Control Area			Total Area		
	n	x̄	SD	n	x̄	SD	n	x̄	SD
Scup	6	1999.6	757.4	6	1875.8	1216.6	21	1570.3	1375.8
Butterfish	6	1052.7	848.2	6	365.2	284.3	21	455.6	612.8
Summer Flounder	6	501.7	163.5	6	496.0	296.8	21	507.8	296.5
Silver Hake	6	236.3	133.4	6	265.5	143.3	21	294.5	193.2
Monkfish	6	75.8	83.9	6	58.4	73.8	21	134.9	145.6
Winter Flounder	6	170.0	113.7	6	55.6	40.8	21	79.9	85.7
Windowpane	6	155.9	127.6	6	156.4	95.1	21	97.4	107.2
Fourspot	6	72.0	65.9	6	61.5	28.4	21	69.4	43.0
Black Seabass	6	80.7	100.9	6	62.6	102.5	21	40.9	80.9
Yellowtail	6	27.5	19.5	6	1.6	2.0	21	13.4	21.0
Squid	6	12.2	9.0	6	22.5	11.7	21	17.0	10.5
Haddock	6	6.3	11.0	6	9.4	12.0	21	10.7	12.7

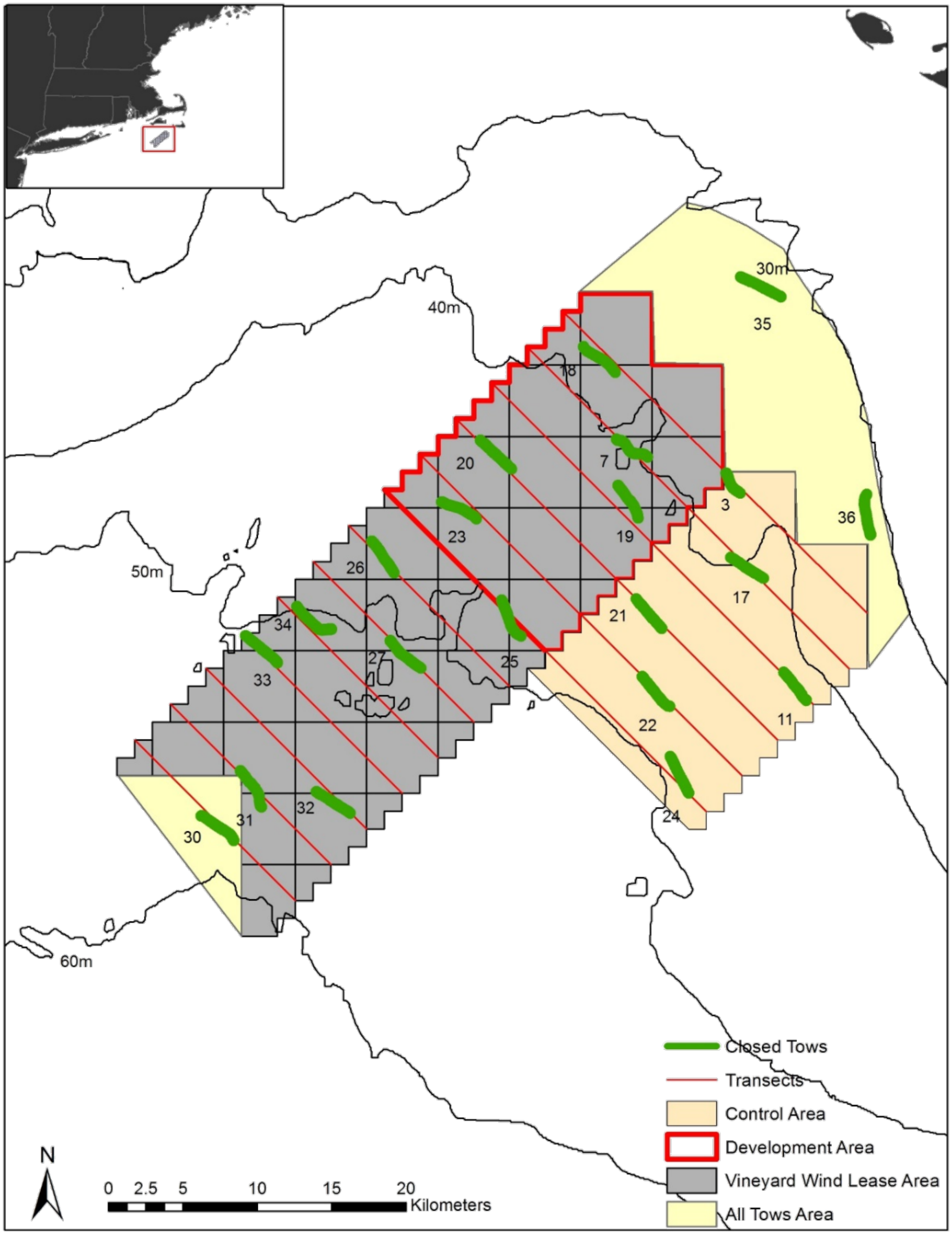

Figure 1. Trawl locations (green) in the Vineyard Wind lease area (grey) and candidate control areas.

If otter trawling is not feasible in the turbine field, other sampling approaches will be needed. For example, BOEM (2013) provides guidance on a beam trawl survey, but there would be no historical or regional beam trawl survey to provide baseline or regional information. Another option for sampling finfish is underwater video (Schobernd et al. 2014). Video sampling can help to monitor fish abundance on or near turbines. Video sampling may be a valuable option if mobile gear cannot be fished in the turbine area, or if survey catches are not permitted. Baseline sampling would be needed to determine the duration of video sampling needed to detect an impact.

Optical Survey of Benthic Invertebrates and Habitat

Region-wide drop camera surveys have been conducted by SMAST since 2003 (Stokesbury et al. 2004, Bethoney and Stokesbury 2018). The survey design is systematic centric, including four samples at each stations, and stations are placed in a (5.56 km) grid. Baseline sampling with the SMAST drop camera survey was completed in the lease area in 2012 and 2013. The survey sampled a diverse assemblage of benthic invertebrates and habitats, and the spatial resolution of stations has been sufficient for quantifying changes in abundance of several species in a beyond BACI design (e.g., scallops, skates, flounder, hake, echinoderms, sponges, bryozoan/hydrozoa; Stokesbury and Harris 2006). Greater spatial resolution (1.5 km grid) has been used for several fine-scale studies, and may be necessary for some lower density resources (e.g., squid egg mops). We recommend that the monitoring plan should emulate the SMAST drop camera survey as much as possible to allow comparison with regional and baseline sampling. Drop camera surveys should be conducted annually in summer in the lease area. Fishermen reported that squid egg mops are expected to be in the Vineyard Wind lease area from May to July (Hatfield and Cadrin 2002), so drop camera surveys conducted in late spring and early summer would be optimal for monitoring squid mops. A more specific proposal for a drop camera survey in the Vineyard Wind lease area is in Appendix E.

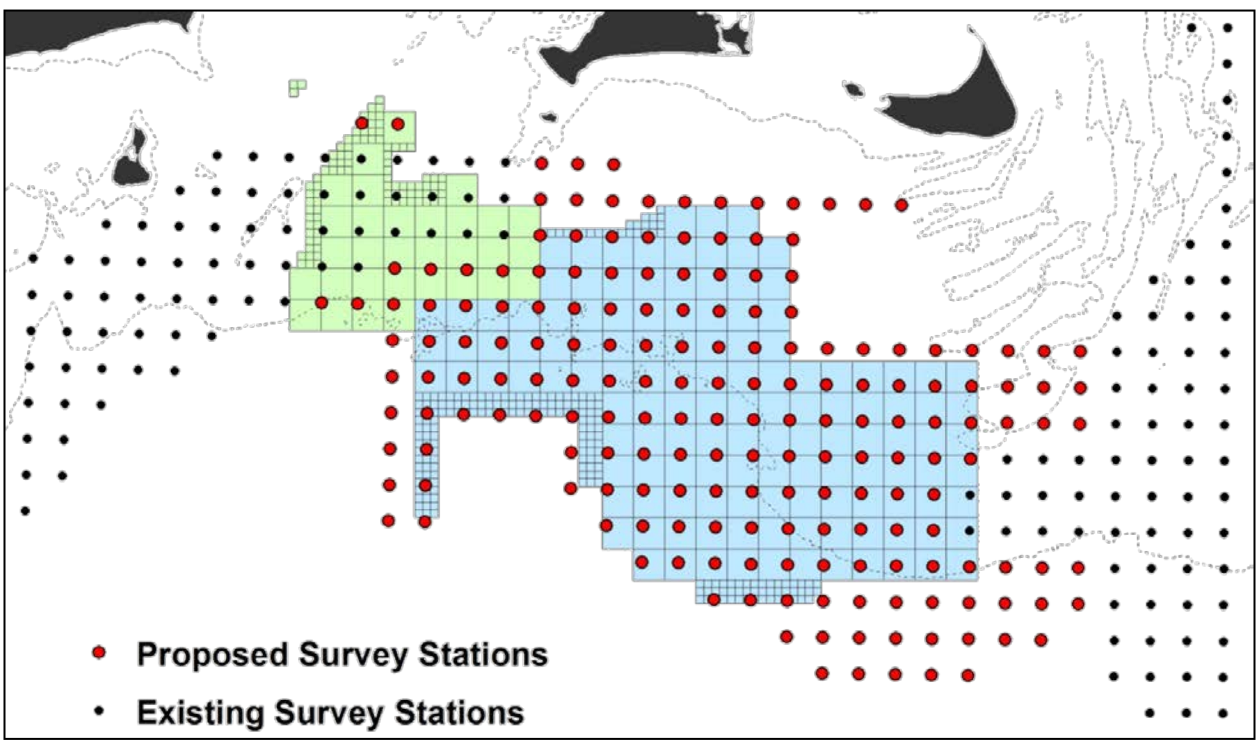

Figure 2. SMAST drop camera stations sampled in 2012 and 2013 (proposed survey stations were funded by MA Clean Energy Commission).

Ventless Trap Survey

The Massachusetts Division of Marine Fisheries has conducted a ventless lobster trap survey since 2006 (Pugh et al. 2015). MADMF contracts Massachusetts lobstermen to set and haul ventless traps from June through September at random locations in state waters to monitor the abundance of lobster, crabs, whelk and some finfish (www.mass.gov/service-details/american-lobster-research-and-monitoring). The Rhode Island Department of Environmental Management Division of Marine Fisheries has also conducted a ventless trap survey since 2006 (RIDEM 2018). A Southern New England Cooperative Ventless Trap Survey was developed in 2014 to assess the seasonal distribution, movement, and habitat use of the American lobster and Jonah crab in the Cox's Ledge Wind Energy Area for a pre-construction baseline for lobster and Jonah crab (www.cfrfoundation.org/snecvts). The survey is a partnership with commercial lobstermen to sample 24 lease blocks in the lease area (Figure 3). RI/MA Wind Energy Area were selected for the study, based on their potential for development of offshore wind energy (see map below). Biological sampling is conducted within each lease block two times per month from May to November. Survey gear includes trawls of six ventless traps and four standard traps, which are sampled twice per month, with a target soak time of 5 days. The Block Island Wind Farm Ventless Trap Survey (CoastalVision 2013) also offers an example of a survey designed to detect wind farm impacts.

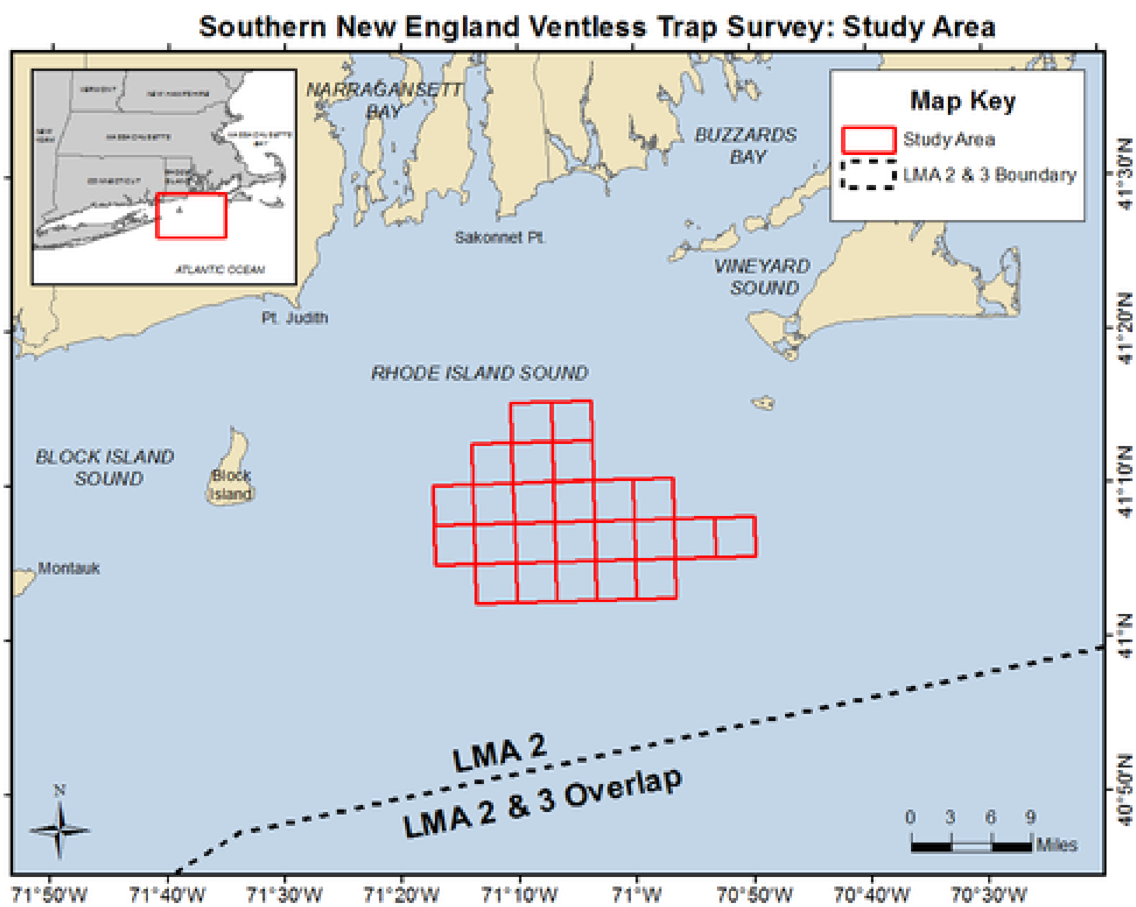

Figure 3. Twenty-four lease blocks sampled by the Southern New England Cooperative Ventless Trap Survey (from www.cfrfoundation.org/snecvts)

In conjunction with the ventless trap survey within the RI/MA wind energy area, a lobster tagging program is being implemented to determine the seasonal movement patterns and habitat use of lobsters. From May - November, 3,000 lobsters will be tagged with t-bar tags that allow for monitoring of broad scale lobster movements. Additionally, 100 lobsters will be equipped with acoustic tags that allow for more detailed, continuous tracking of lobster movements. Recoveries of tagged lobsters will be made by the sea samplers and monetary reward systems are in place to promote tag reporting by commercial lobstermen.

We recommend that the monitoring plan should emulate existing ventless trap surveys as much as possible to allow comparison with regional and baseline sampling. The Massachusetts Lobstermen's Association in conjunction with the Lobster Foundation of Massachusetts is planning to collaborate with the MA DMF and SMAST to develop a ventless trap survey that will cover the Vineyard Wind lease area to monitor the lobster resource pre, during and post construction. Although there are some differences in sampling designs and protocols among the regional ventless trap surveys (Table 5), standardized catch rates from the different surveys should be comparable. The sampling design should be consistent with other regional ventless trap surveys. Including a black sea bass pot in the string of traps can also help to monitor reef-oriented finfish. SMAST will conduct at sea data collection and data analysis utilizing commercial lobster vessels as the platform for the at sea data collection and ventless trap deployment. A more specific proposal for a ventless trap survey in the Vineyard Wind lease area is in Appendix F.

Table 5. Attributes of regional lobster surveys.

	ASMFC	DEM/DMF	FEDERAL	SNECVTS	BIWF
#VENTLESS	3	3	-	6	10
#VENTED	3	3	-	4	2
DESIGN	Stratified by depth	Stratified by depth and region	-	Stratified by aliquot	-
FREQUENCY	2x/month	2x/month	-	2x/month	2x/month
SOAK TIME	3 nights	3 nights	-	5 days	5 nights
TIME OF YEAR	Jun-Sep	Jun-Aug/Sep	Fall/Spring	May-Oct	May-Oct
TRAP SIZE	40x21x16"	40.25x21.5x16.25"	-	40x21x16"	40x20x16"
VENT SIZE	Varies by state	5 3/4" x 1 15/16"	-	5 3/4" x 1 15/16"	-
ENTRY SPACING	2 5"	2 5" and 8.25"	-	2 5"	-
BAIT	Varies by state	-	-	Skate	Skate
NOTES	Fixed location throughout survey	Fixed location throughout survey	Use trawl survey data	Fixed location throughout sampling period	Final report coming Spring 2019

Plankton Survey

The NEFSC samples phytoplankton, microzooplankton, and mesozooplankton on the northeast U.S. continental shelf from Cape Hatteras to the Gulf of Maine during the spring and fall bottom trawl surveys and during some of the Ecosystem Monitoring cruises in winter, late spring, late summer and late autumn (www.nefsc.noaa.gov/epd/oceanography/shelfwide.html). The current Ecosystem

Monitoring survey protocol has been conducted since 1988. Zooplankton and ichthyoplankton are sampled using paired 61-cm Bongo samplers equipped with 333 micron mesh nets. At each station, double oblique tows are made to 5 m above the bottom, or to a maximum depth of 200 m. A digital flowmeter is suspended in the mouth of each Bongo sampler to quantify the volume of water filtered by each net. Plankton tows are conducted at a speed of 2.8 km/h. Plankton samples are preserved in a 5% solution of formalin in seawater, and stored for subsequent laboratory analysis. Over 300 plankton taxa are sorted, identified and enumerated, including major target species in commercial and recreational fisheries. We recommend that the monitoring plan should emulate the NEFSC Ecosystem Monitoring survey protocol as much as possible to allow comparison with regional and baseline sampling.

SMAST has conducted zooplankton surveys in Buzzards Bay since 1987 (Chute and Turner 2001). Samples are collected monthly at 8 stations around the Bay. Similar to the Ecosystem Monitoring survey, a double oblique net tow is made at each station, from the surface to approximately 1 m above the bottom with a flowmeter and two zooplankton nets: a 48 cm diameter 0.102 mm mesh and a 0.202 mm mesh net with a 75 cm mouth diameter. Fish larvae from 32 genera were identified, including commercially and recreationally important species (tautog, scup, butterfish, winter flounder, black sea bass, mackerel, menhaden, hake, whiting, herring summer flounder, witch flounder, and weakfish).

Plankton surveys tailored to sampling lobster larvae have also been conducted in the region. Dedicated lobster larvae surveys have been conducted in Buzzards Bay since 1976. SMAST sampled the Bay in 2006-2007 using a comparable survey protocol as the 1976-1982 surveys by NEFSC and MADMF (Milligan 2009), and the survey was conducted again in 2018. The survey protocol includes three fifteen-minute, 4 knot parallel net tows at seven stations throughout Buzzards Bay, sampled weekly. An aluminum push net 2.66 m wide, 0.66 m deep, 6.66 m long, made of 1300 µm nylon mesh size of, and length of. The zooplankton contents of each tow are fixed in 10% formalin:seawater solutions on board, then transferred into 70% ethanol in the laboratory, and all lobsters are sorted from other zooplankton. If a multispecies zooplankton survey is not sufficient for sampling lobster larvae, a supplemental lobster larvae survey may be needed. A more specific proposal for a plankton survey in the Vineyard Wind lease area is in Appendix F.

Supplemental Studies

The requirement to monitor the distribution of recreational and commercial fishery resources and cumulative impacts of multiple wind farm development areas requires integrated regional monitoring of abundance as well as inferences of movement and dispersal from and to the impact area. As examples, MADMF (2019) recommended regional research on habitat mapping, cod spawning, larval transport, and fish tagging as priorities. Eggs and larval dispersal can be evaluated using biophysical models, informed by field observations of spawning time and location. Movement patterns of juvenile and adult life stages as well as the spatial scope for regional studies can be informed by conventional and electronic tagging.

The surveys recommended above will sample between turbines and along the cable route, but supplemental monitoring will be needed to monitor local effects of turbines. Optical survey transects (e.g., Schobernd et al. 2014) should be conducted from the turbine to surveyed areas to monitor ecological succession and spatial extent of ‘reef effect.’

Physical oceanography of the northeast U.S. continental shelf is relatively well understood, and oceanographic models can predict transport of eggs and larvae. For example, the transport and retention of larvae in the region has been quantified for sea scallops (e.g., Tian et al. 2009), groundfish (e.g., Boucher et al. 2013) and lobster (Casey et al. 2018; Figure 4). Larval transport models can be informed by the location and timing of spawning from surveys of spawning adults.

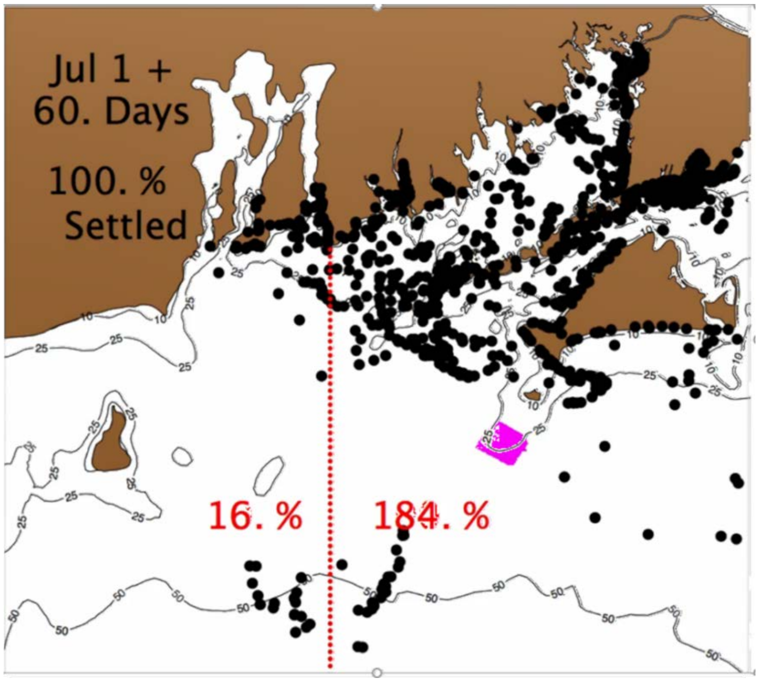

Figure 4. Dispersal of lobster larvae from a spawning site in southern New England (spawning area: pink; settlement locatin: black).

Conventional and electronic tagging have been successful for the evaluating movement patterns of the commercially and recreationally important species in the lease area. For example, conventional tagging has been used to evaluate the dispersal of spawning cod tagged on Cox Ledge (Figure 5; Loehrke 2014). Acoustic tagging has been valuable for determining residence in specific areas and seasonal fidelity to the area (e.g., Zemeckis et al. 2014), and data from archival tags can be used with oceanographic models to estimate seasonal distribution (e.g., Liu et al. 2017; Figure 6). Secor and Bailey (2018) deployed acoustic receivers in the Maryland Wind Energy Area to measure seasonal patterns of incidence by Atlantic sturgeon and striped bass and model their rates of transit through the area. Acoustic and archival tags are the most cost-effective approach for monitoring highly migratory species, because the Atlantic Cooperative Telemetry Network (www.theactnetwork.com) facilitates data sharing between researchers utilizing acoustic telemetry so that many species tagged by other programs can be detected in the monitoring array, and species tagged in the monitoring plan can be detected in other arrays. Similarly, coordination with the Canadian Ocean Tracking Network (oceantrackingnetwork.org) may help to study regional distribution and impacts.

Analysis of fishery monitoring data may be the most effective approach to detecting impact on highly migratory species. Such analyses can also supplement the proposed surveys for detecting impacts on other recreational and commercial target species. However, as discussed with fishermen and regulators, logbooks from commercial and for-hire recreational fishermen do not have the spatial resolution needed to evaluate local impacts, and alternative monitoring (at-sea observers, electronic logbook, electronic monitoring) would be needed to use fishery monitoring data in the impact analysis.

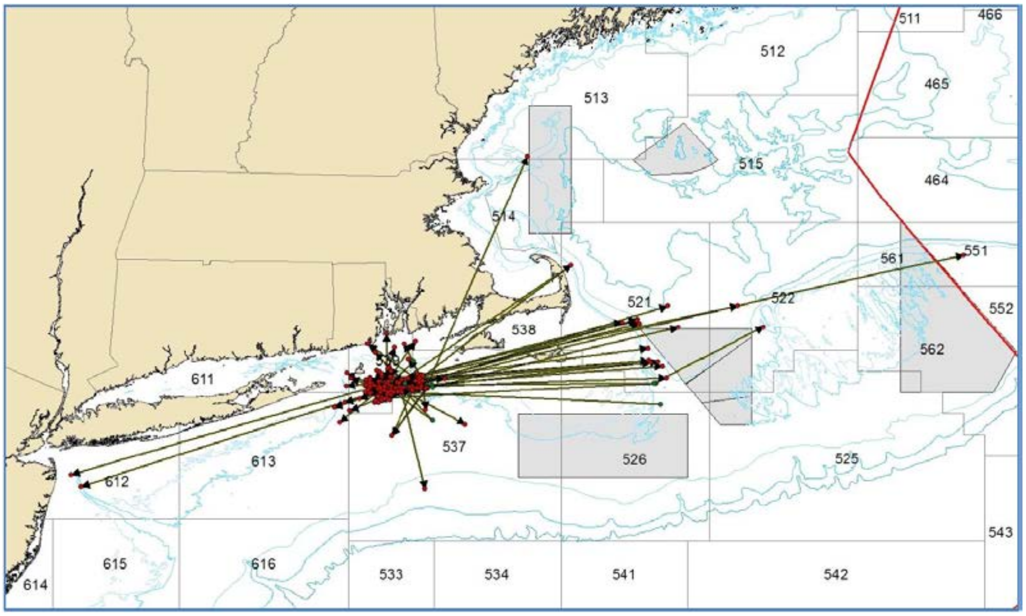

Figure 5. Movements of spawning cod tagged on Cox Ledge and south of Block Island (green circles: release location; red circles: recapture location).

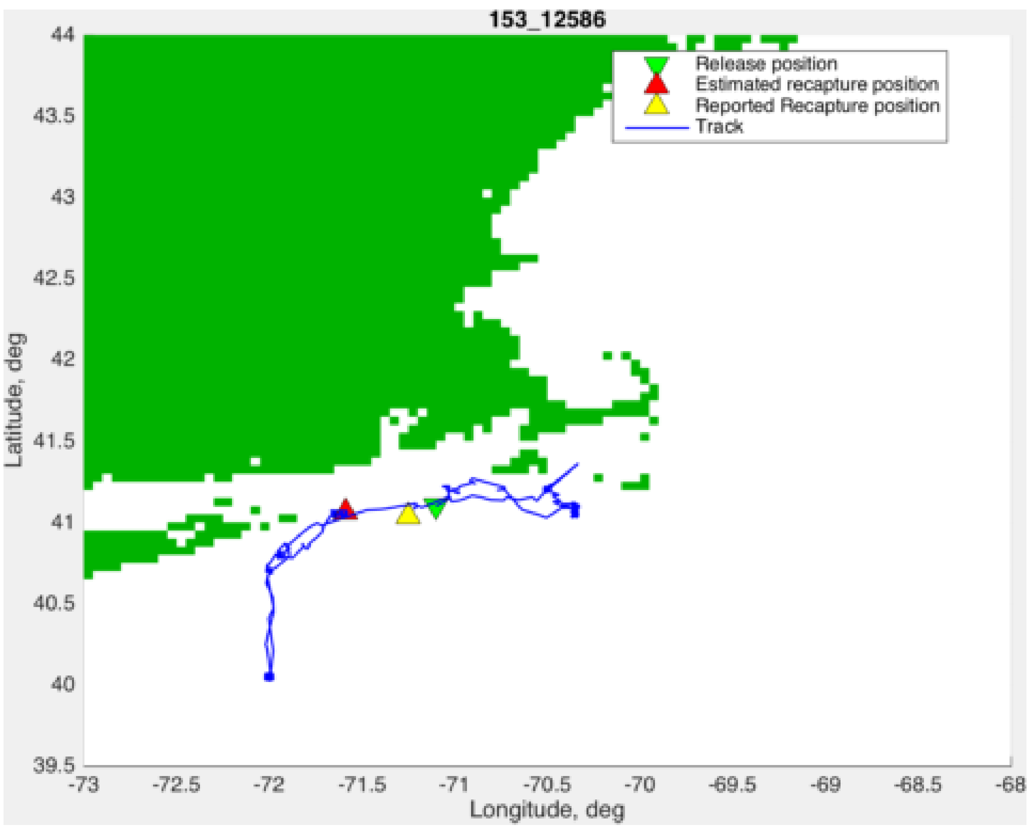

Figure 6. The most probable track and associated total posterior distribution for an Atlantic cod released on Cox Ledge with an archival tag.

Implementation

We recommend a collaborative approach to the monitoring program. A scientific advisory group should be formed to review annual monitoring data, review data analyses and interpretations, and recommend improvements to the monitoring plan if needed. We also recommend collaboration with the fishing industry to include their local ecological knowledge and expertise with fishing gear. For example, each survey should be designed and conducted in collaboration with active fishermen who have expertise fishing in the area and who have an understanding of the regional dynamics and distribution of target species. In addition to the scientific advisory group, we support the recommendation made by workshop participants to form a Fishermen's Monitoring Working Group to provide their perceptions of local and regional changes in fishery resources, review results from the monitoring plan, and recommend revisions to the monitoring plan.

Several of the recommended surveys can be combined. For example, larval sampling can be conducted during the ventless-trap survey; lobster can be tagged, released and recaptured from the ventless-trap survey; finfish can be tagged, released and recaptured from the trawl survey. Such multi-disciplinary sampling may also help to support more integrated analysis of information from each survey.

Additional monitoring will be needed to address fishermen's concerns about the effects of noise and electromagnetic fields on fishery resources. Acoustic sampling should be conducted during construction and operation, possibly in association with other monitoring surveys. Experience with ocean cables suggests that best practice for mitigating the effects of electromagnetic fields is burial of the cable. Therefore, regular monitoring of the cable route with optic or sonar surveys are recommended to ensure sufficient burial would be appropriate.

Fishermen workshop participants and MADMF (2018) identify ocean quahog as a commercial fishery target species that may be impacted by the Vineyard Wind development. The existing benthic sampling and recommended drop camera surveys cannot effectively monitor ocean quahog density, and hydraulic dredging would be needed to monitor their relative density. However, the New England Fishery Management Council is concerned about the impact of hydraulic dredging on fishery habitats in nearby Nantucket Shoals. Therefore, regulatory agencies will need to evaluate the tradeoffs of potential impacts from the wind farm and hydraulic dredge surveys.

6. Acknowledgements

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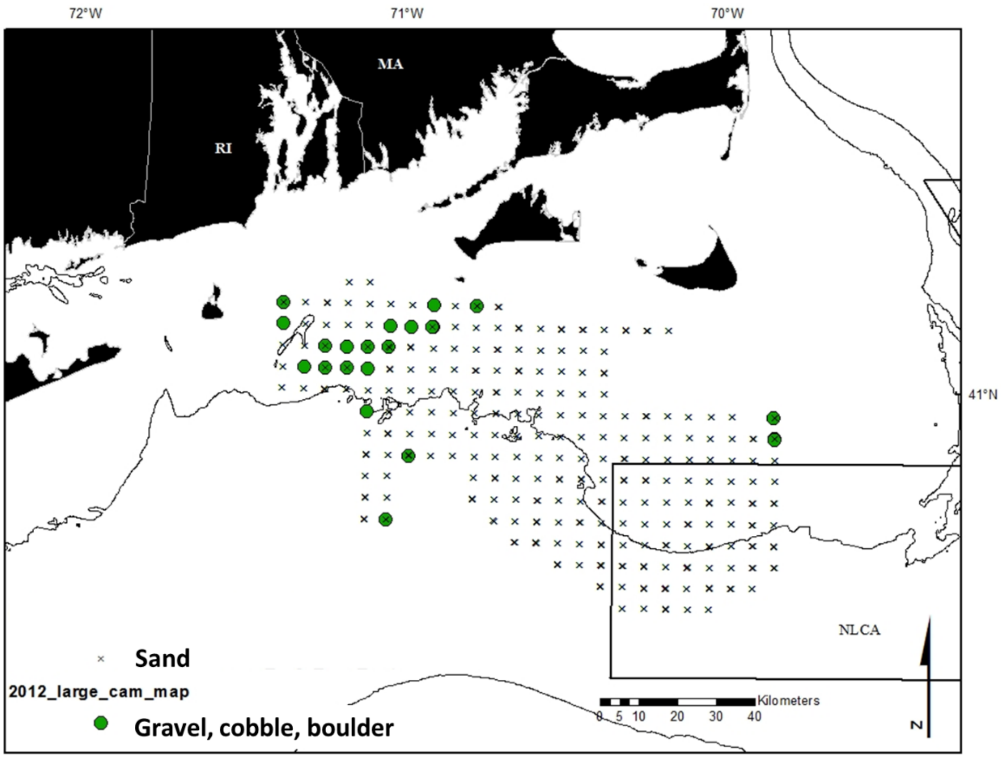
Appendix A. Baseline Drop Camera Surveys

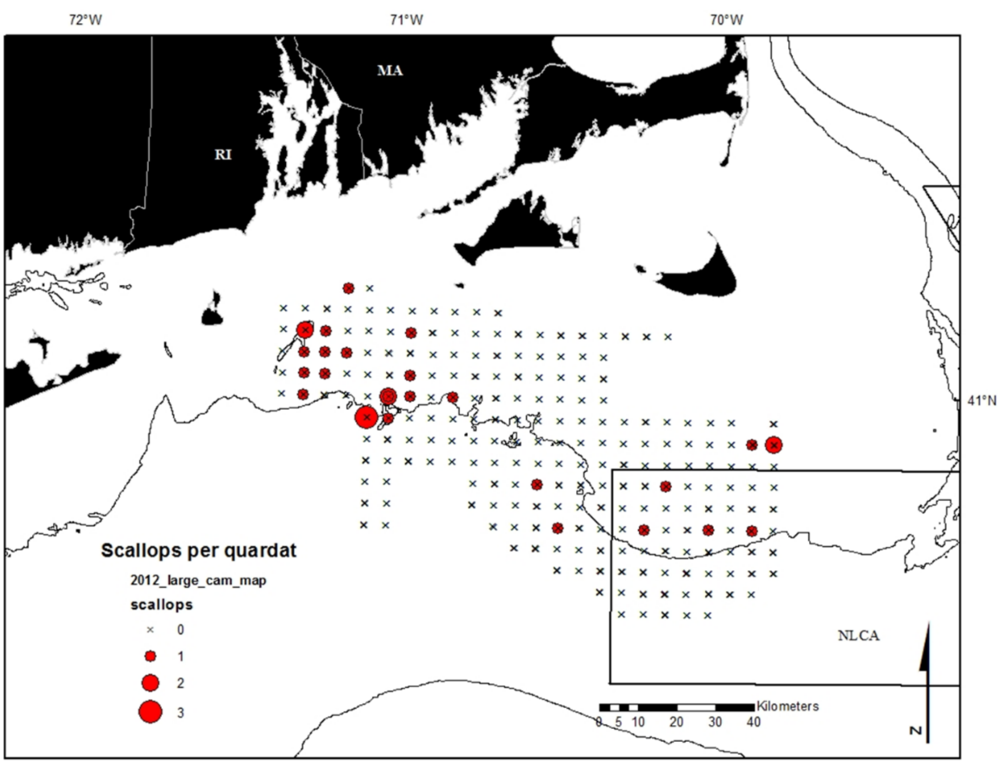
Table A1. Percentage of quadrats containing each substrate type in the windfarm lease locations (WF) in 2012 (n = 896) and 2013 (n = 903) compared to the entire 2012 continental shelf survey (CS, n = 9588), Georges Bank (GB, n = 4916) and the Mid-Atlantic (MA, n = 4672).

	2012	2013			
%	WF	WF	CS	GB	MA
Sand	80.9	99.0	67.8	51.6	77.9
Sand ripple	19.1	1.0	31.6	47.5	21.7
Shell debris	67.3	59.2	94.3	96.2	96.4
Silt	82.9	93.1	50.0	18.8	68.9
Gravel	5.3	5.1	11.5	22.5	4.6
Cobble	2.9	4.0	4.5	9.7	1.0
Rock	2.9	3.7	1.6	3.1	0.5

Table A2. Similarity index comparison between 2012 and 2013 (same stations)

species	2012	2013	2012%	2013%	sim. Index	% Diff
holes	185	49	28.3	11.8	11.8	16.5
sandDollar	178	105	27.2	25.2	25.2	2.0
seaStars	69	24	10.6	5.8	5.8	4.8
skate	46	21	7.0	5.0	5.0	2.0
hake	31	5	4.7	1.2	1.2	3.5
scallops	25	15	3.8	3.6	3.6	0.2
bHydra	23	101	3.5	24.3	3.5	-20.8
sum	654	416	100	100	64.9	


72°W
71°W
70°W
41°N
MA
RI
NLCA
Sand
2012_large_cam_map
Gravel, cobble, boulder
Kilometers
0 5 10 20 30 40
N


72°W
71°W
70°W
41°N
MA
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Kilometers
0 5 10 20 30 40
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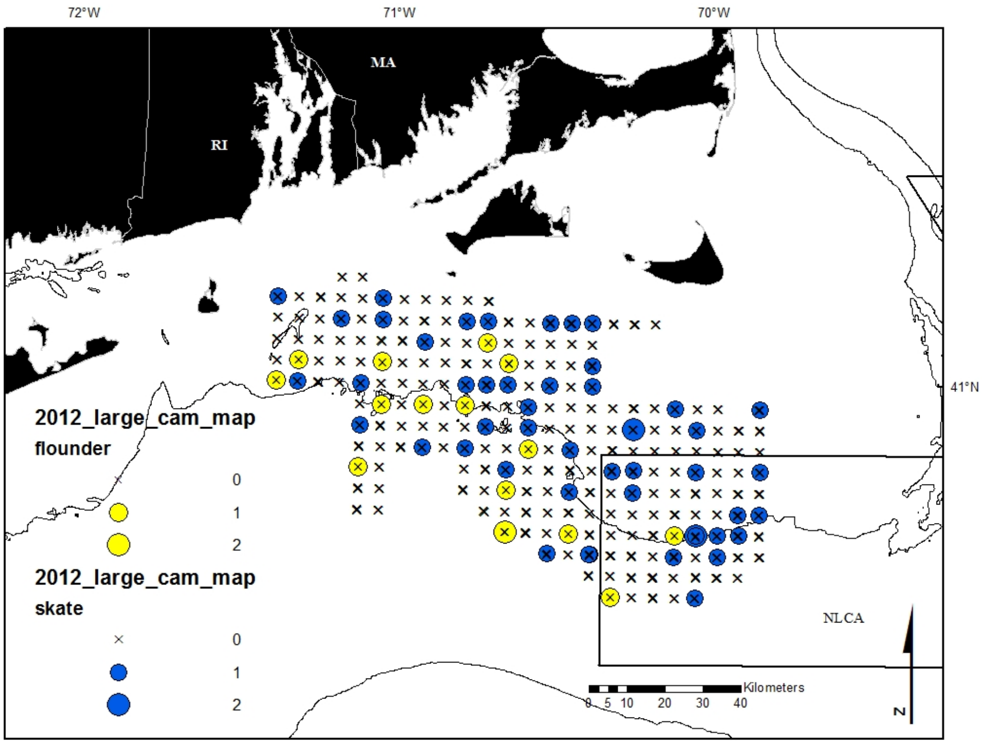
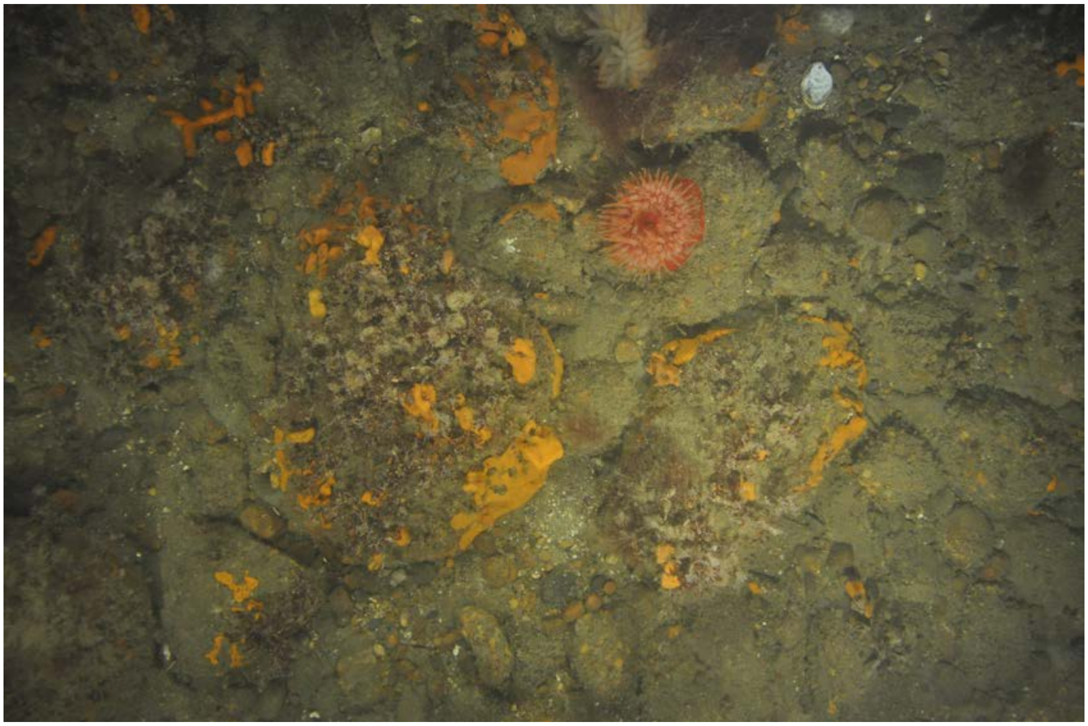
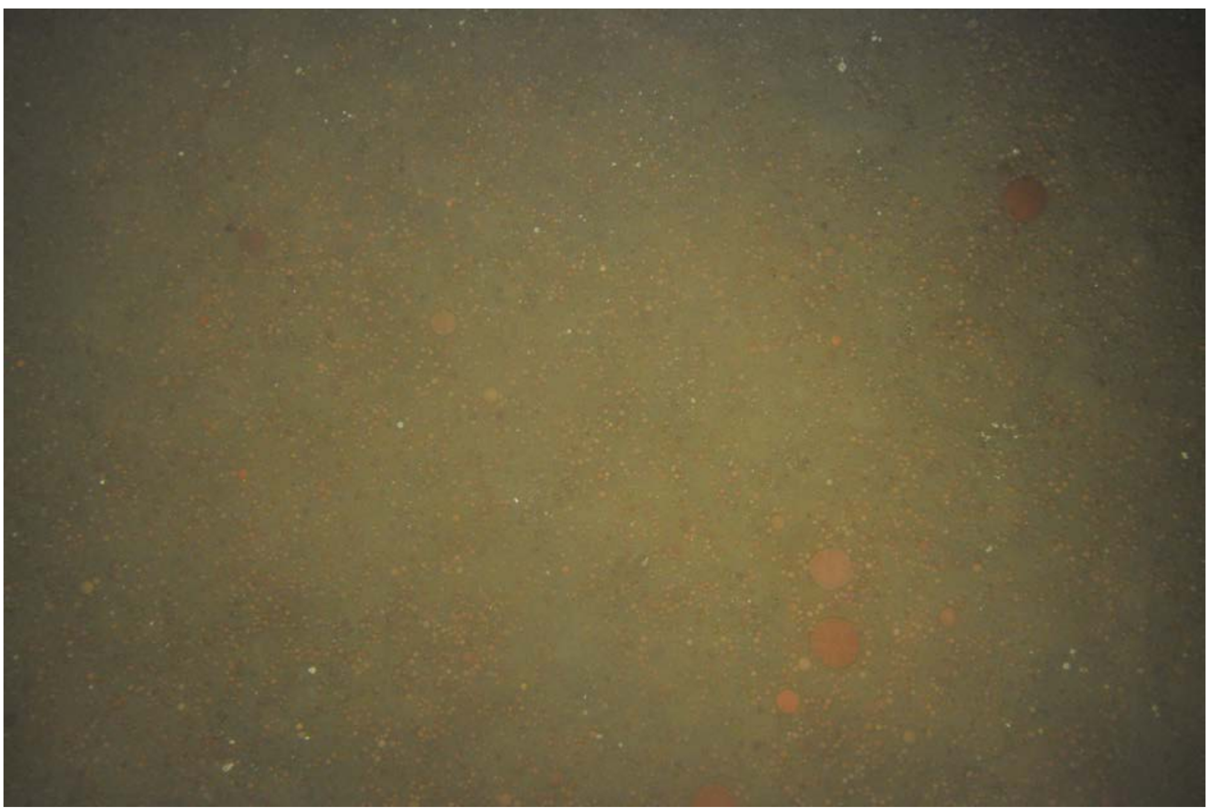
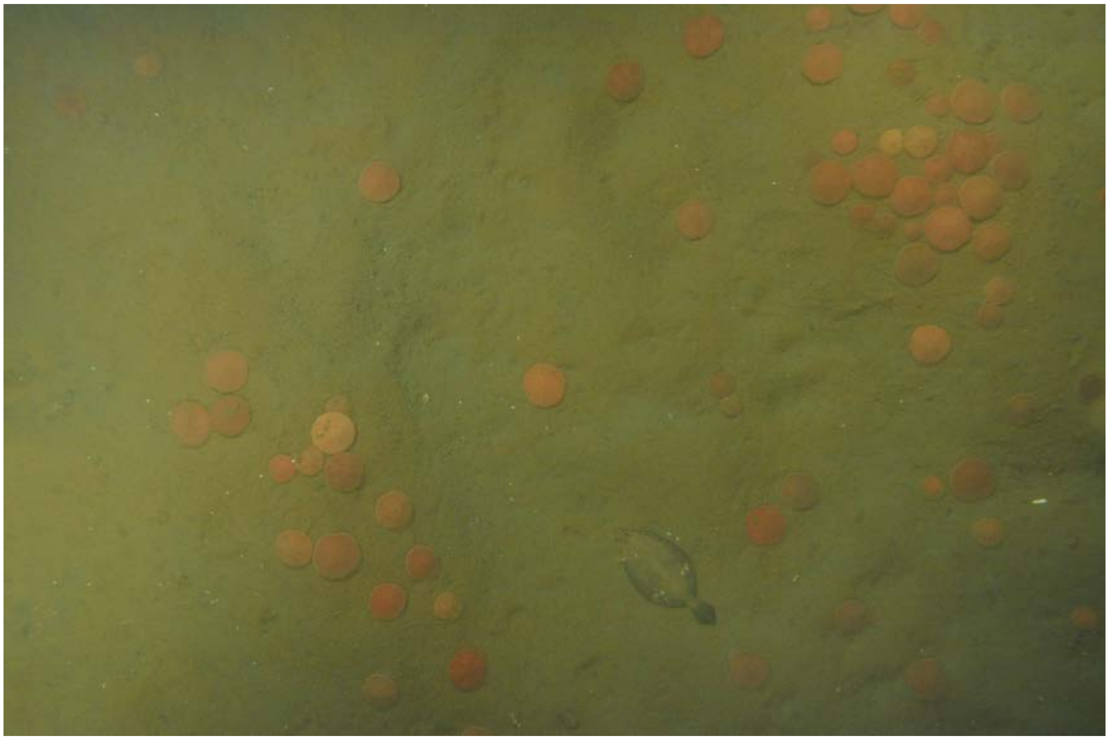




Note that this image includes squid egg mops (top, center) and was taken on Cox Ledge, in the MA-RI Wind Energy Area, but not in the Vineyard Wind lease area.





Final Report

2018 Vineyard Wind Groundfish Bottom Trawl Survey

Report prepared by:

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In August 2018 the University of Massachusetts Dartmouth, School for Marine Science and Technology (SMAST) was contacted by Vineyard Wind to conduct a pilot survey of their lease area (675 km^2) and an adjacent control area (306 km^2). The SMAST video trawl survey was started in 2013 and has shown success on Georges Bank and the Gulf of Maine using video technology placed in the codend of an otter trawl. The design includes open codend tows with a camera used to observe and count fish as they pass through the net along with periodic closed codend tows to collect biological data. The overall goal is to improve estimates of the abundance, spatial distribution, size structure, and length-weight relationship of the groundfish community. The pilot study was used to see if the video trawl survey would work in the area and act as baseline data for a before after control impact study. The initial plan was to use a combination of open and closed codend tows on 19 transects that were 8nm long and 2nm apart within the Vineyard Wind lease area and control area (Figure 1).

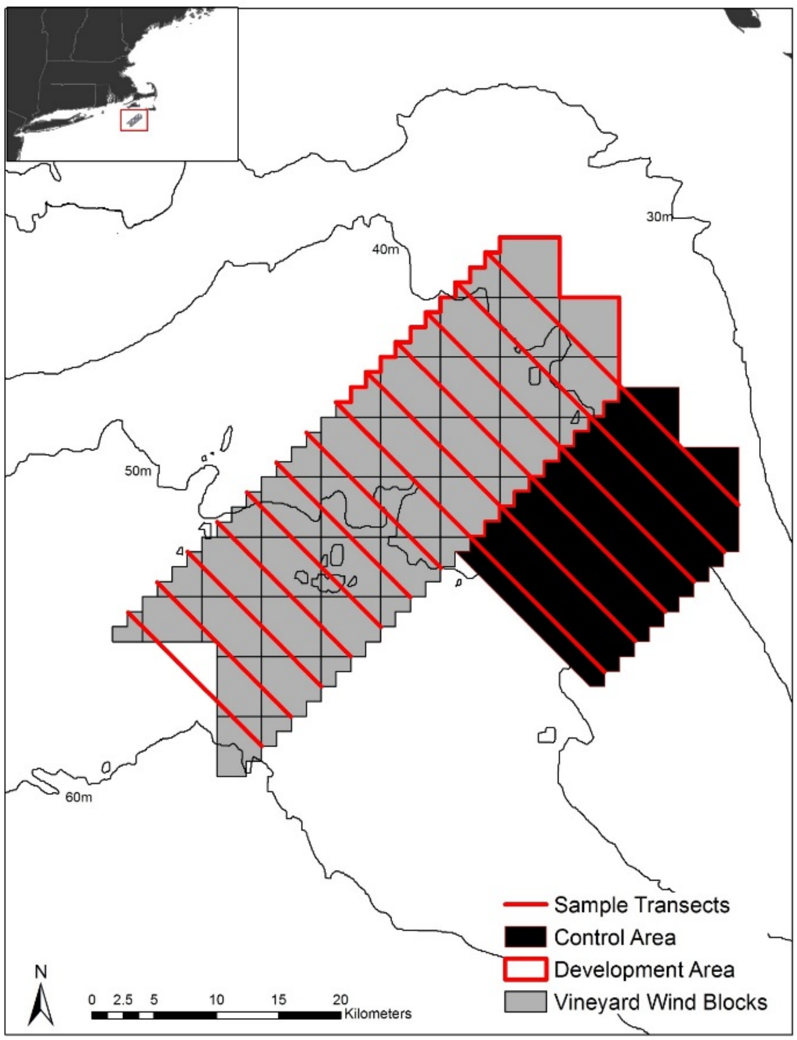

Figure 1. Proposed transect locations in the Vineyard Wind lease area and adjacent control area.

The pilot survey took place from September 26th to October 4th, 2018 on the F/V Justice out of New Bedford, MA. The survey team consisted of a captain, three crew members, and three SMAST scientists. During the first set of tows we realized the video was obscured by mud clouds which made it difficult to see any fish species passing thorough the net. The crew tried several iterations to the net such as adjusting the headrope, sweep, and adding several floats to the codend without success. The last resort to increase the visibility in the camera was to add an extra 15 fathoms of groundcable. We hoped the groundcable would place the net farther behind the doors therefore the mud cloud would be diminished by the time it reach the camera and visibility would increase. This also was not successful and we realized the video component would not work in the Vinyard Wind lease area due to the soft sediment type.

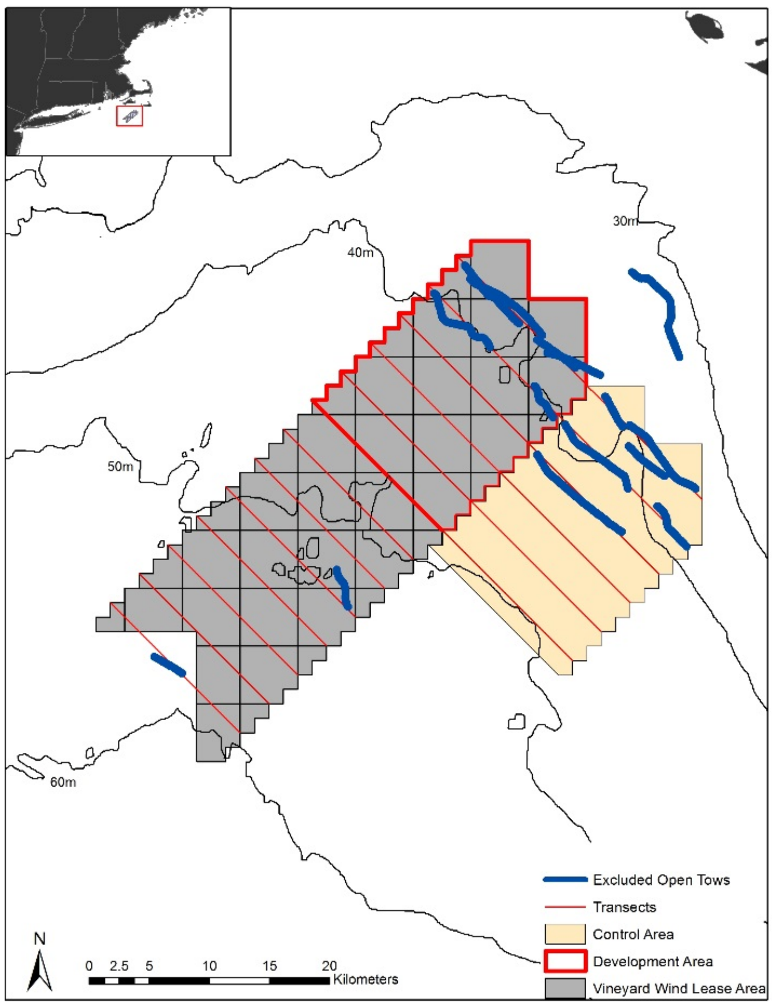

Figure 2. Open tow locations in the Vineyard Wind lease area and adjacent control area. The open codend tows are indicated by blue lines. The 14 open tows were excluded from analysis.

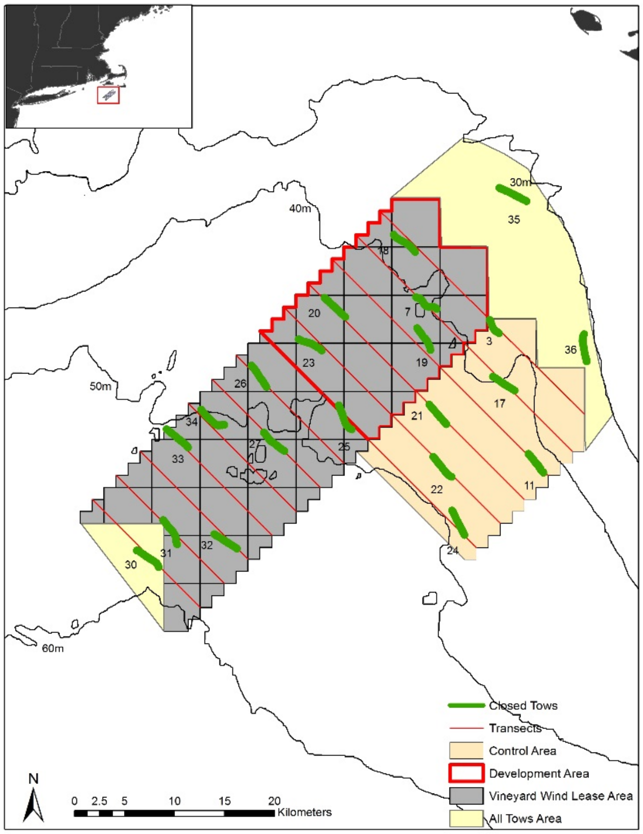

Figure 3. Closed tow locations in the Vineyard Wind lease area and adjacent control area. The entire Vineyard Wind lease area is in grey, the development area is within the red boundary, the adjacent control area is in beige, and the control area including all tows is in yellow.

Table 1. Tow location from the 21 successful closed codend tows completed. The data includes tow number, location, duration, depth, themperature, doorspread, speed, and area swept.

Tow Number	Start Latitude	Start Longitude	End Latitude	End Longitude	Tow Duration (hrs)	Mean Depth (m)	Mean Temperature (Celsius)	Mean Doorspread (km)	Vessel Speed (km/hr)	Area Swept (km^2)
3	41.01909	-70.3567683	41.03115	-70.3684483	0.35	36.99	16.46	0.039	4.82	0.07
7	41.05064	-70.4562883	41.04009	-70.4311767	0.50	37.93	16.24	0.042	5.33	0.11
11	40.8945	-70.3013583	40.91126	-70.319565	0.50	39.91	17.55	0.043	5.21	0.11
17	40.96775	-70.3368167	40.98029	-70.3633867	0.50	39.70	17.35	0.051	5.38	0.14
18	41.10641	-70.4838517	41.09119	-70.4581033	0.48	37.27	16.16	0.051	5.66	0.14
19	41.00304	-70.4379	41.02271	-70.454465	0.50	39.22	16.07	0.044	5.06	0.11
20	41.04866	-70.5652033	41.03151	-70.5398317	0.50	42.91	15.55	0.047	5.80	0.14
21	40.95415	-70.4383967	40.93676	-70.41797	0.50	42.07	15.86	0.050	5.20	0.13
22	40.8894	-70.4102933	40.9072	-70.4326017	0.50	45.12	15.38	0.054	5.40	0.14
23	41.00094	-70.56727	41.01086	-70.5952383	0.50	44.08	15.29	0.052	5.37	0.14
24	40.83722	-70.3940967	40.85907	-70.409155	0.50	47.21	15.52	0.052	5.70	0.15
25	40.93042	-70.5299667	40.9519	-70.5457917	0.52	45.66	14.83	0.050	5.59	0.14
26	40.98632	-70.65055	40.96746	-70.6323317	0.48	45.36	14.89	0.052	5.26	0.13
27	40.92631	-70.6344633	40.90998	-70.60967	0.50	49.65	14.34	0.051	5.60	0.14
30	40.81794	-70.78242	40.80348	-70.75621	0.50	53.99	13.50	0.057	5.73	0.16
31	40.82412	-70.7347283	40.84579	-70.752055	0.52	51.94	14.08	0.054	5.93	0.16
32	40.83411	-70.6911667	40.82138	-70.66355	0.50	53.89	15.65	0.058	5.50	0.16
33	40.91172	-70.7240583	40.92753	-70.7498783	0.52	51.06	13.84	0.057	5.52	0.16
34	40.94577	-70.7094733	40.93271	-70.6813783	0.52	49.37	13.95	0.051	5.93	0.16
35	41.13834	-70.3263283	41.15004	-70.3589467	0.50	30.24	17.51	0.033	6.22	0.10
36	41.01955	-70.25557	40.99517	-70.2520267	0.50	29.89	17.78	0.048	5.53	0.13
Mean					0.49	43.50	15.61	0.049	5.51	0.14
Total					10.38					2.84

During the survey we employed a combination of open and closed codend tows. A total of 14 open tows resulting in 17 hours of video could not be used for analysis due to visibility (Figure 2). We completed a total of 21 closed codend, one tow at each of the 8nm transects and two tows north of the lease and control areas (Figure 3). The closed codend tows (n=21) ranged from .35 to .52 hours in duration, and the mean vessel speed ranged from 4.82 to 6.22 km/hr. The mean doorspread was .049 km with a total area swept of 2.84 km^2. The mean temperature was 15.61 °C and the mean depth was 43.50m.

Skates were the most abundant species in the catch followed by scup, butterfish, spotted/red hake, silver hake, and sea robin (Table 2).

Table 2. Count and weight of each species observed in the catch of the 21 completed tows from fall 2018 survey. * were estimated by basket counts.

Tow #	Total Count	Total Weight (kg)
Skates	21978	NA
Scup	13973*	4415.25
Butterfish	11878*	1175.12
Spotted/Red Hake	9845*	1527.13
Silver Hake	9078*	893.17
Sea Robin	3059	NA
Windowpane Flounder	1443	241.36
Fourspot Flounder	1175	207.03
Summer Flounder	967	1439.61
Gulfstream Flounder	890	14.33
Dogfish	838	NA
Squid	724	47.96
Crabs	627	NA
Winter Flounder	624	227.75
River Herring	294	30.64
Yellowtail Flounder	221	38.65
Monkfish	206	423.99
Barndoor Skates	149	30.36
Scallops	122	NA
Black Seabass	109	91.71
Haddock	30	32.28
Sculpin	30	NA
Lobster	11	7.74
Bluefish	8	20.37
Ocean Pout	8	NA
American Eel	3	3.44
Filefish	3	0.03
Sea Raven	2	NA
Mackerel	2	NA
Torpedo Ray	1	7.80
White Hake	1	0.73
Sea Cucumber	1	NA

Estimates of density (kg/km^2) and biomass (mt) were calculated for twelve species by examining the observed catch and the area swept by the survey net during each of the closed codend tows. Speed during fishing activity was aimed at 3 knots. The data was used to calculate the mean speed (km/hour) of the vessel during each survey tow. The duration of each tow was converted from minutes to fraction of an hour for area swept calculations.

Net mensuration equipment (NOTUS sensors) was placed on the trawl doors and the headrope to monitor the dimensions of the net and allow for the area swept to be calculated during each tow. The mean doorspread (m) observed on each survey tow was calculated from the data files and converted to km. The area swept (km^2) by the survey net was calculated for each tow as follows:

$$Area\ swept\ (km^2) = doorspread\ (km) * tow\ speed\ \left(\frac{km}{hr}\right) * tow\ duration\ (hr)$$

The density for the species of interest was calculated for each survey tow as follows (Gunderson 1993):

$$density\ \left(\frac{kg}{km^2}\right) = \frac{catch\ (kg)}{area\ swept\ (km^2)}$$

The size of the study area was estimated in ArcGIS by calculating the area of a polygon for the development area, control area, and entire area for all tows.

The biomass for the species of interest in the study area was estimated as follows:

$$biomass\ (kg) = density\ \left(\frac{kg}{km^2}\right) * size\ of\ survey\ area\ (km^2)$$

The efficiency of the survey net has not been investigated to date. Therefore, our calculations of density and biomass are highly conservative because they assume that the survey net is able to catch 100% of the fish that are within the path of the trawl doors (i.e., the net has 100% herding and capture efficiency).

Table 3. Summary of the density (kg/km^2) and biomass (mt) estimates for twelve species using doorspread during the fall 2018 survey. The estimates were calculated for tows completed in the development area, control area, and area encompassing all tows.

Species	Density (kg/km2)								
	Development Area			Control Area			Whole Area		
	n	x̄	SD	n	x̄	SD	n	x̄	SD
Scup	6	1999.6	757.4	6	1875.8	1216.6	21	1570.3	1375.8
Butterfish	6	1052.7	848.2	6	365.2	284.3	21	455.6	612.8
Summer Flounder	6	501.7	163.5	6	496.0	296.8	21	507.8	296.5
Silver Hake	6	236.3	133.4	6	265.5	143.3	21	294.5	193.2
Monkfish	6	75.8	83.9	6	58.4	73.8	21	134.9	145.6
Winter Flounder	6	170.0	113.7	6	55.6	40.8	21	79.9	85.7
Windowpane	6	155.9	127.6	6	156.4	95.1	21	97.4	107.2
Fourspot	6	72.0	65.9	6	61.5	28.4	21	69.4	43.0
Black Seabass	6	80.7	100.9	6	62.6	102.5	21	40.9	80.9
Yellowtail	6	27.5	19.5	6	1.6	2.0	21	13.4	21.0
Squid	6	12.2	9.0	6	22.5	11.7	21	17.0	10.5
Haddock	6	6.3	11.0	6	9.4	12.0	21	10.7	12.7

Species	Biomass (mt)								
	Development Area (306 km^2)			Control Area (306 km^2)			Whole Area (1251 km^2)		
	n	x̄	SD	n	x̄	SD	n	x̄	SD
Scup	6	602.1	228.1	6	564.8	366.3	21	1933.0	1693.6
Butterfish	6	317.0	255.4	6	110.0	85.6	21	560.8	754.3
Summer Flounder	6	151.1	49.2	6	149.3	89.4	21	625.1	365.0
Silver Hake	6	71.2	40.2	6	79.9	43.1	21	362.5	237.8
Monkfish	6	22.8	25.3	6	17.6	22.2	21	166.0	179.2
Winter Flounder	6	51.2	34.2	6	16.7	12.3	21	98.4	105.4
Windowpane	6	46.9	38.4	6	47.1	28.6	21	119.9	131.9
Fourspot	6	21.7	19.8	6	18.5	8.5	21	85.4	52.9
Black Seabass	6	24.3	30.4	6	18.8	30.9	21	50.4	99.6
Yellowtail	6	8.3	5.9	6	0.5	0.6	21	16.5	25.9
Squid	6	3.7	2.7	6	6.8	3.5	21	20.9	12.9
Haddock	6	1.9	3.3	6	2.8	3.6	21	13.2	15.6

The density and biomass estimates were higher in the development area than the control area for most species (8 of 12 species). There was a significant difference between the development and control area for yellowtail flounder and winter flounder (t-test p=.009 and .043 respectively).

From the baseline data obtained from the pilot study we were able to make a recommendation for future surveys in the Vineyard Wind area. The sample size needed moving forward was determined as follows (Krebs 1989):

$$n = \left(\frac{200CV}{r}\right)^2$$

Where:

r = desired relative error (width of confidence interval as percentage)

CV= coefficient of variation

The number of samples needed was calculated using a relative error of 25% and CV from the density (kg/km2) for the top four most abundant species (Scup, Butterfish, Summer Flounder, and Silver Hake). This is also assuming random distribution. We recommend a minimum of 20 samples in the development area and 20 samples in the control area be completed for each survey.

Distribution Maps and Length Frequency for Groundfish Species

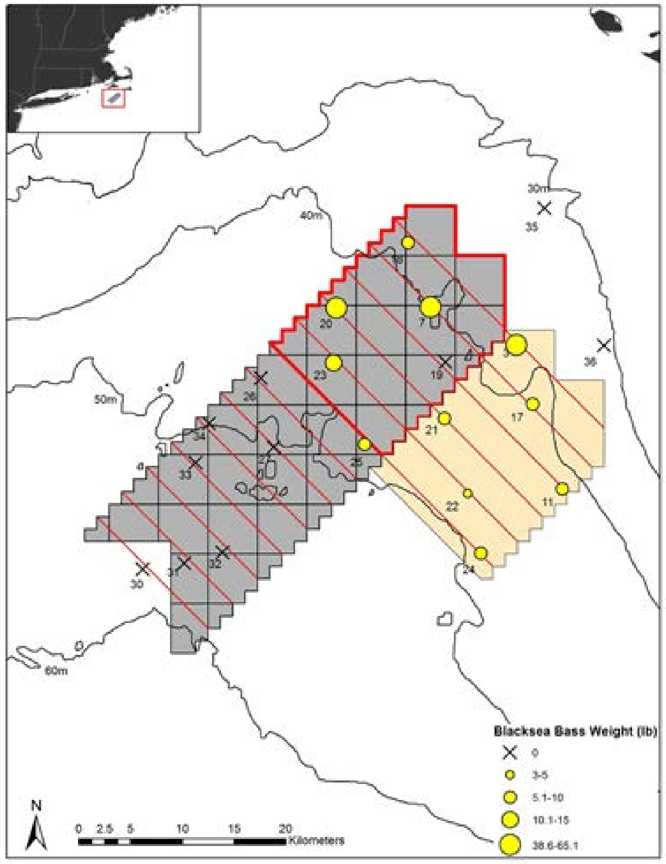

Figure A1. Distribution of black seabass catches observed during the fall 2018 survey.

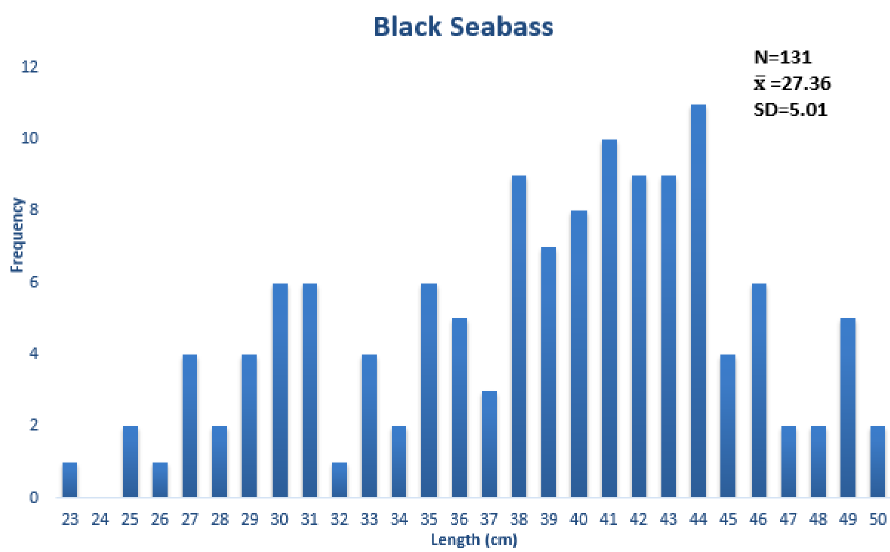

Figure A2. Length frequency distribution of black seabass observed during the fall 2018 survey

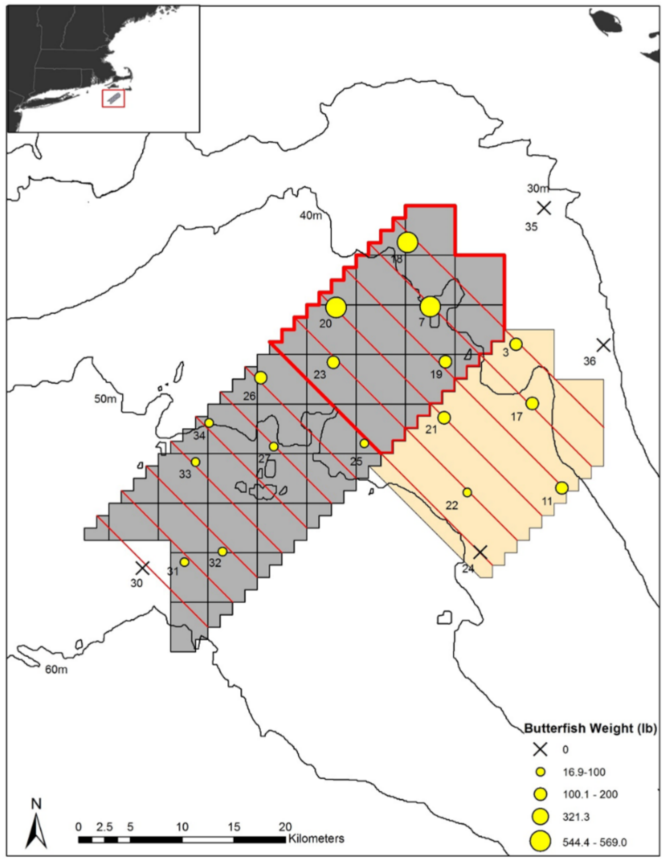

Figure A3. Distribution of butterfish catches observed during the fall 2018 survey.

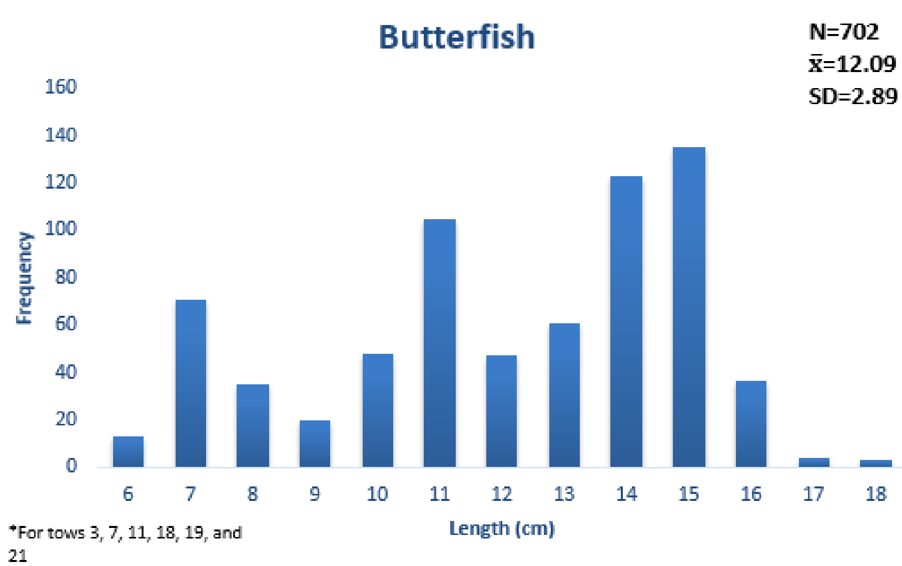

Figure A4. Length frequency distribution of butterfish observed during the fall 2018 survey.

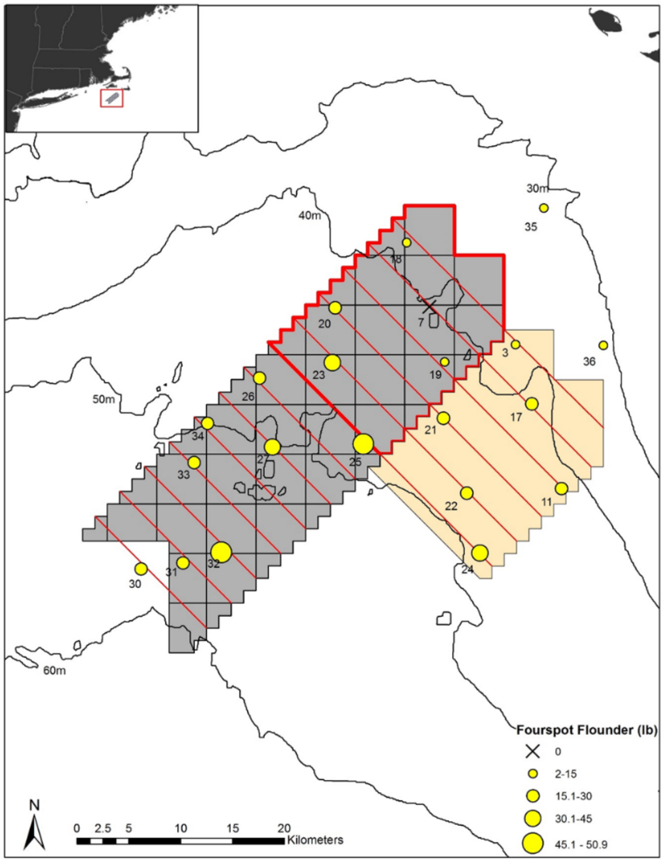

Figure A5. Distribution of fourspot flounder catches observed during the fall 2018 survey.

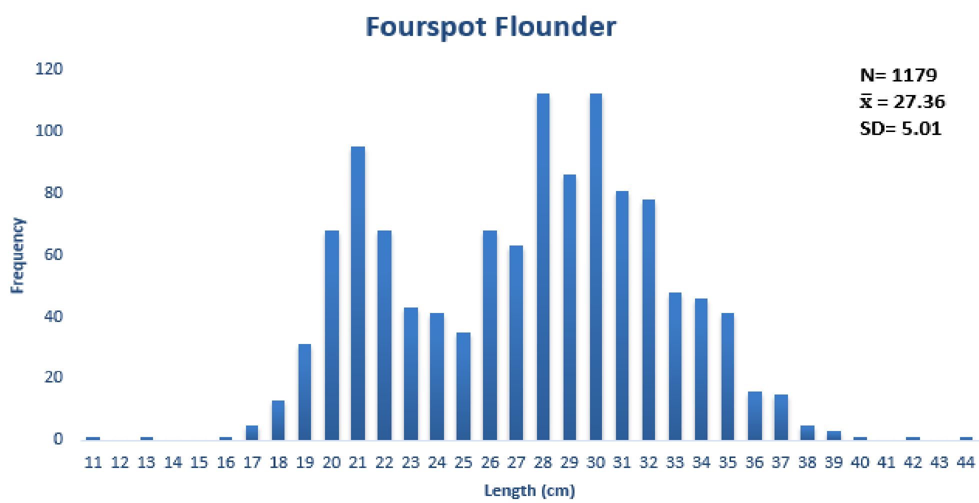

Figure A6. Length frequency distribution of fourspot flounder observed during the fall 2018 survey.

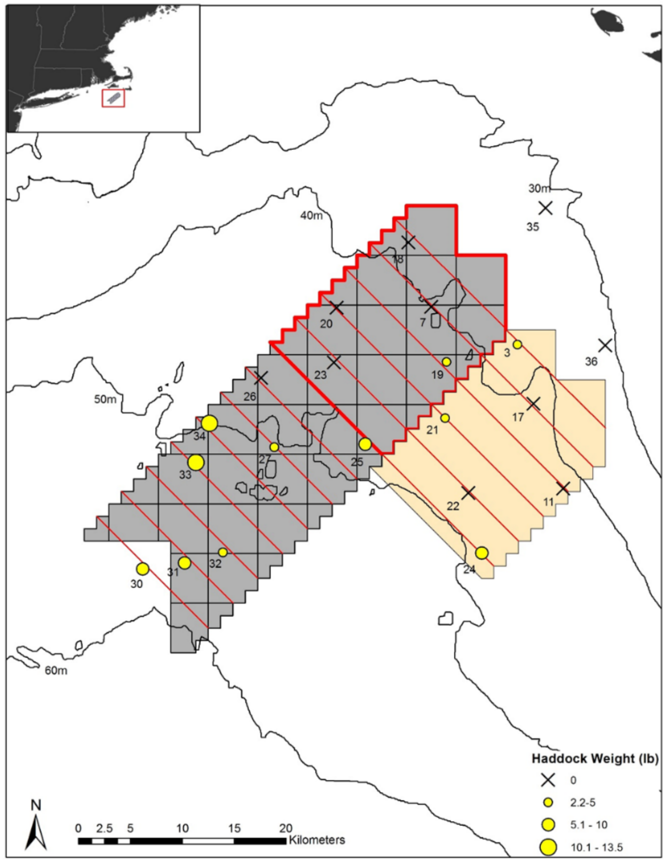

Figure A7. Distribution of haddock catches observed during the fall 2018 survey.

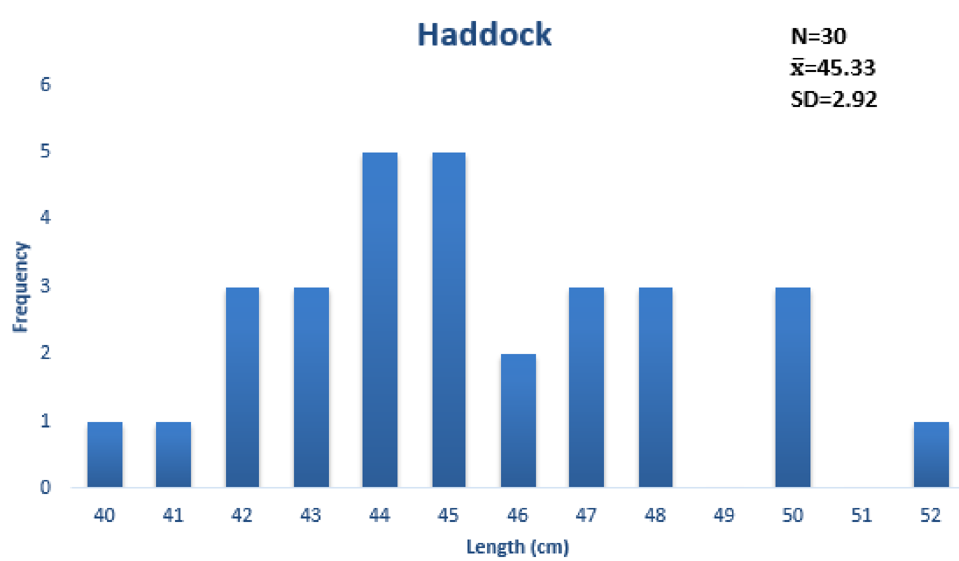

Figure A8. Length frequency distribution of haddock observed during the fall 2018 survey.

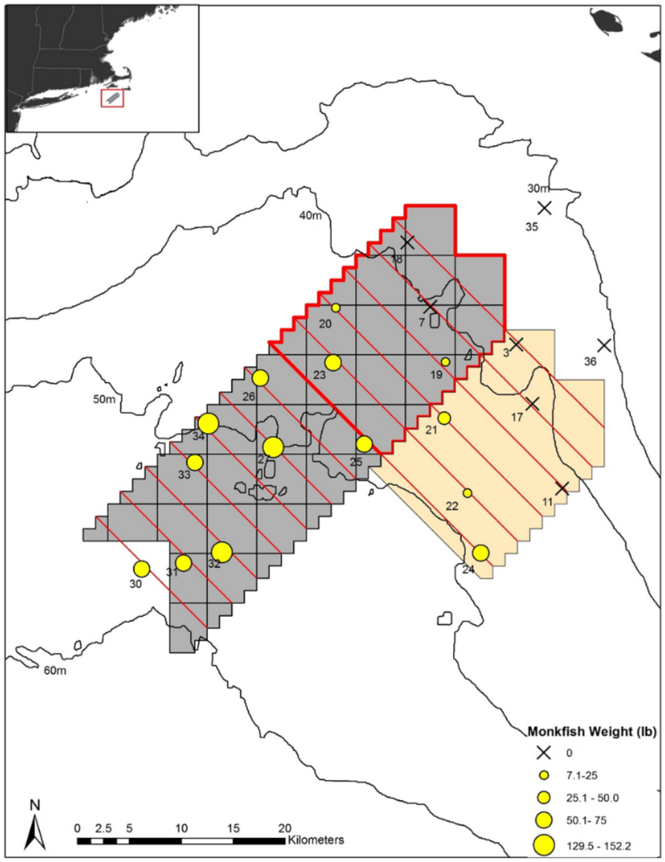

Figure A9. Distribution of monkfish catches observed during the fall 2018 survey.

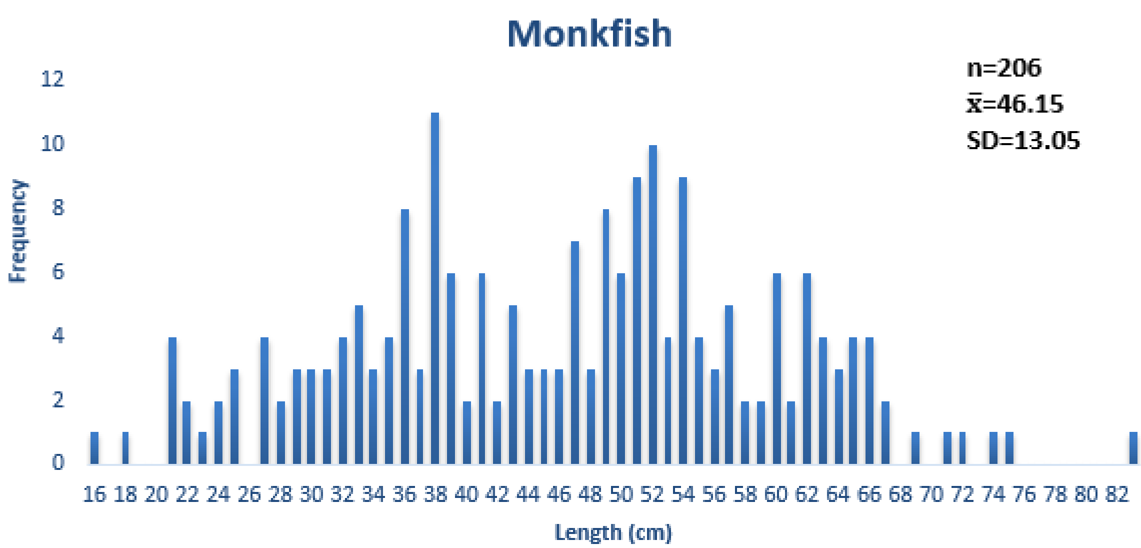

Figure A10. Length frequency distribution of monkfish observed during the fall 2018 survey.

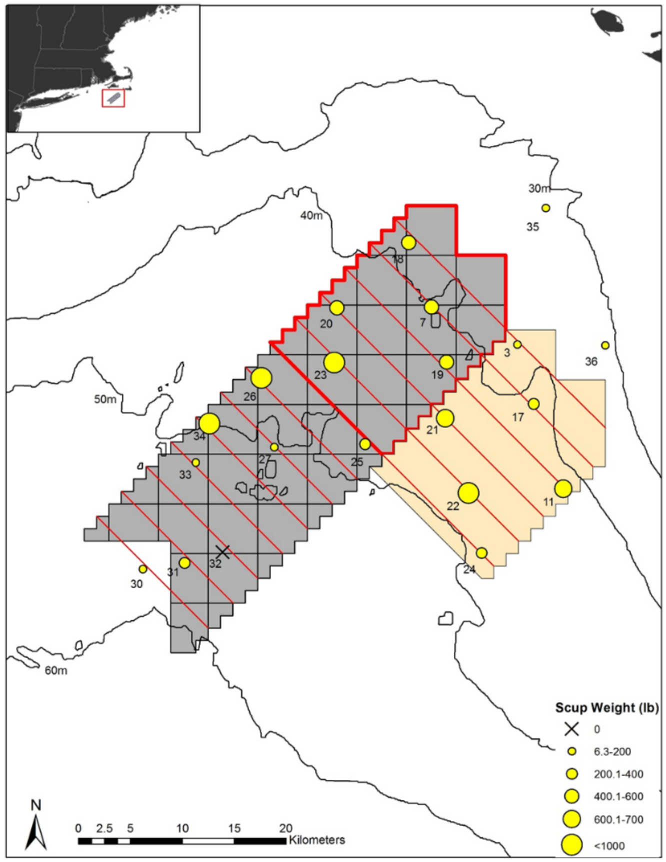

Figure A11. Distribution of scup catches observed during the fall 2018 survey.

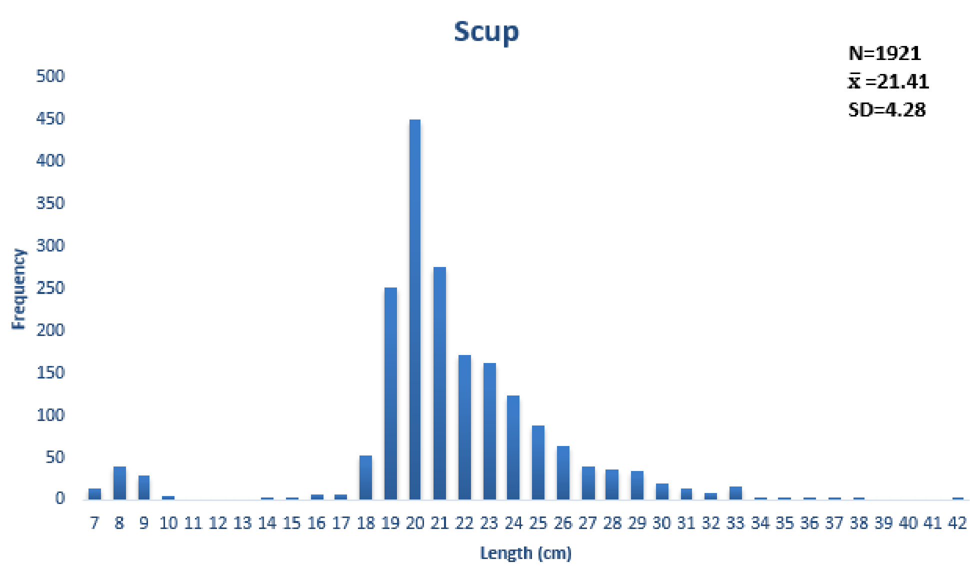

Figure A12. Length frequency distribution of scup observed during the fall 2018 survey.

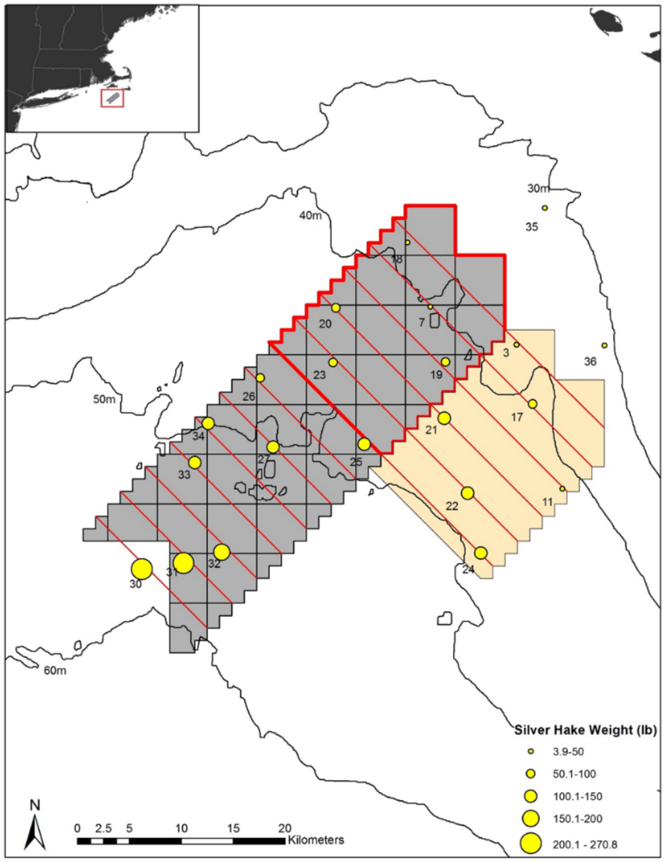

Figure A13. Distribution of silver hake catches observed during the fall 2018 survey.

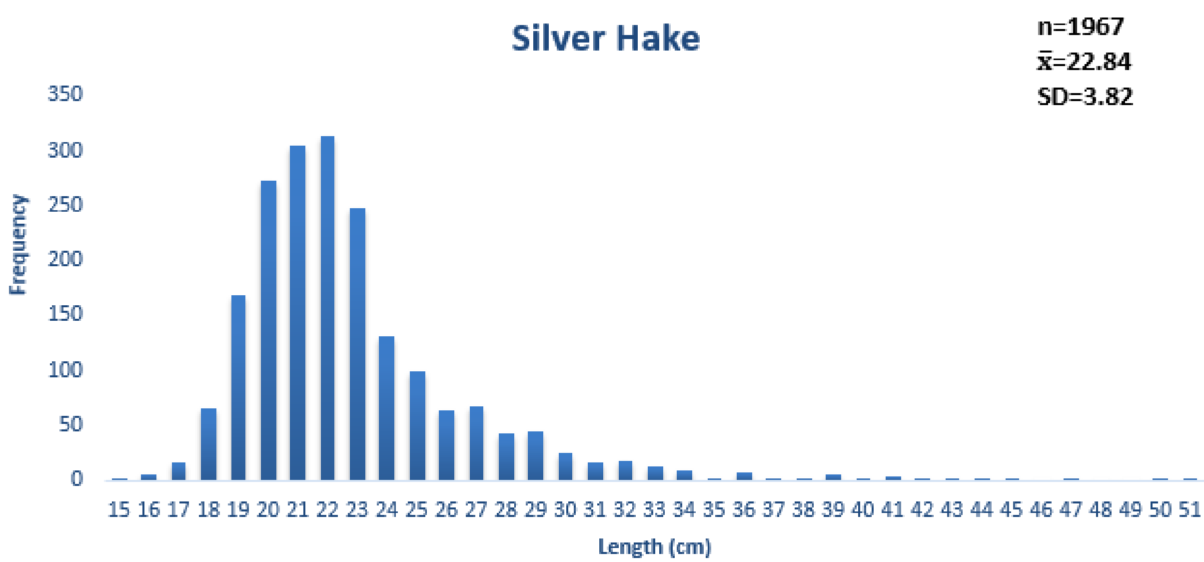

Figure A14. Length frequency distribution of silver hake observed during the fall 2018 survey.

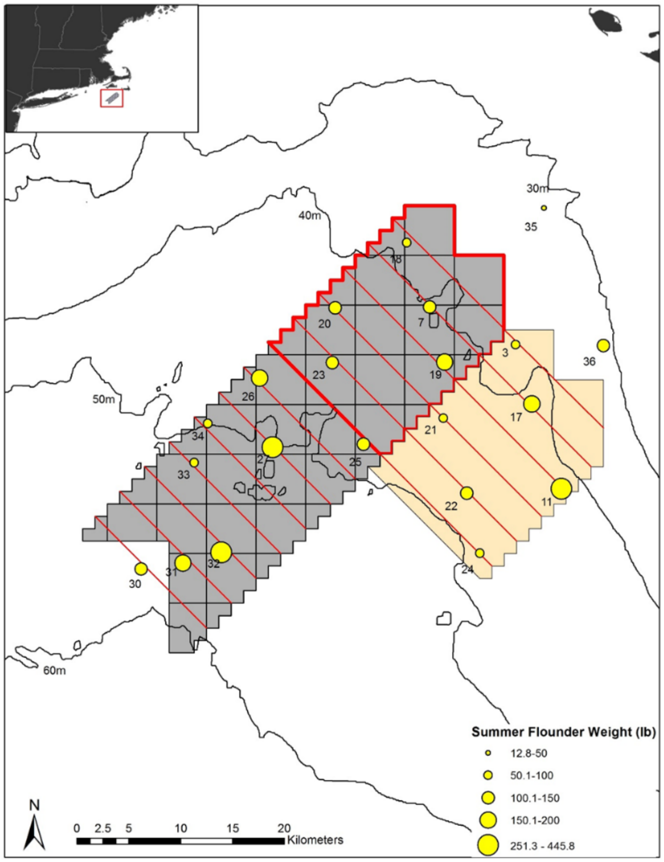

Figure A15. Distribution of summer flounder catches observed during the fall 2018 survey.

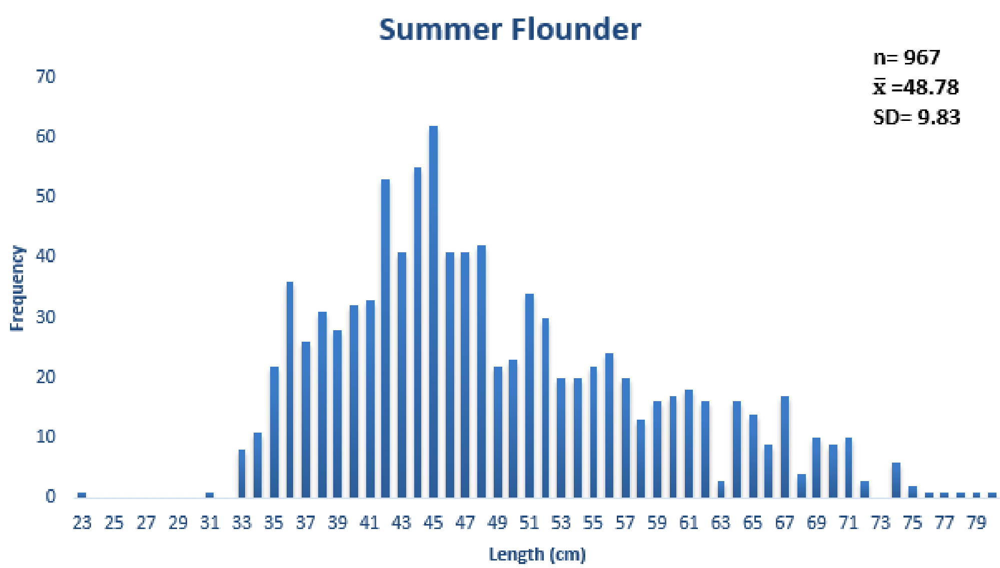

Figure A16. Length frequency distribution of summer flounder observed during the fall 2018 survey.

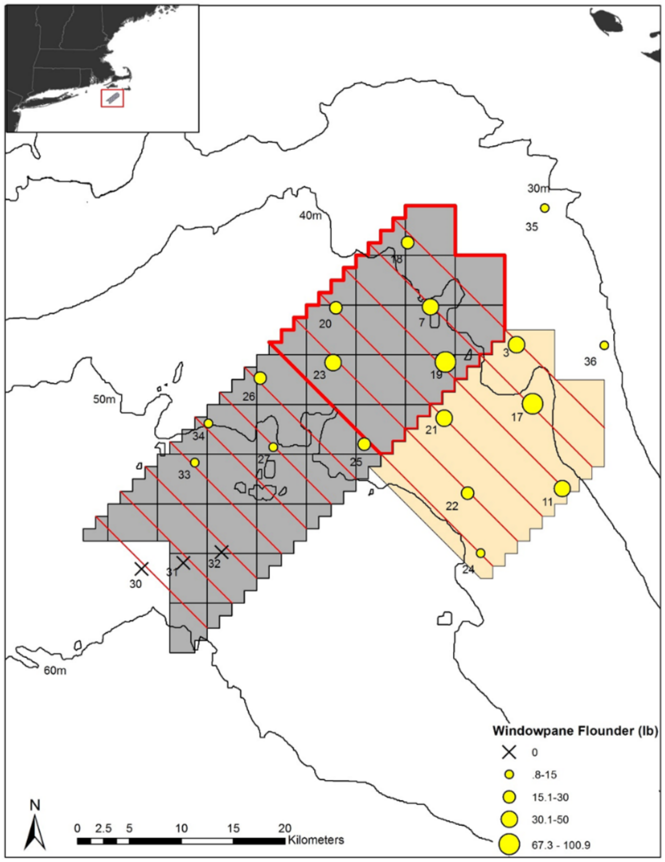

Figure A17. Distribution of windowpane flounder catches observed during the fall 2018 survey.

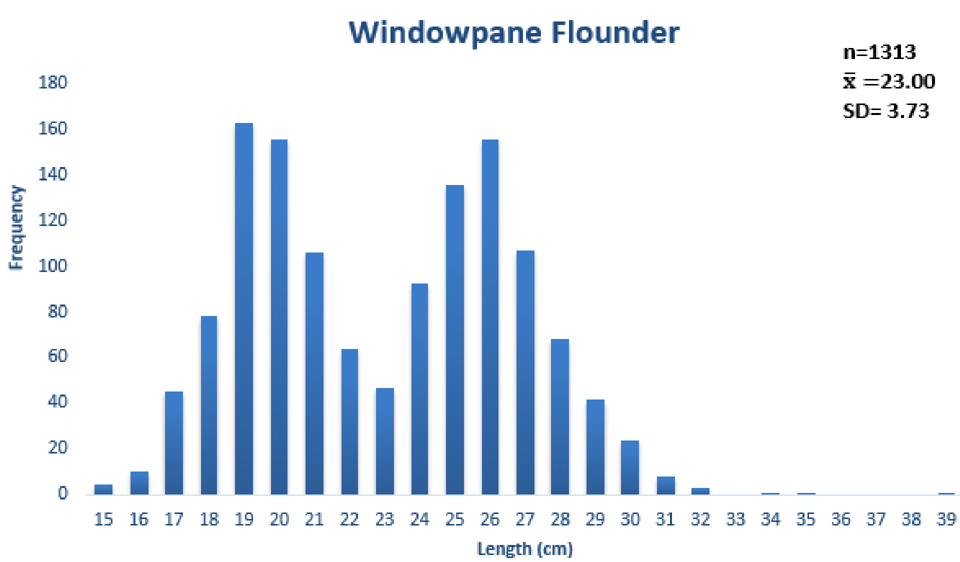

Figure A18. Length frequency distribution of windowpane flounder observed during the fall 2018 survey.

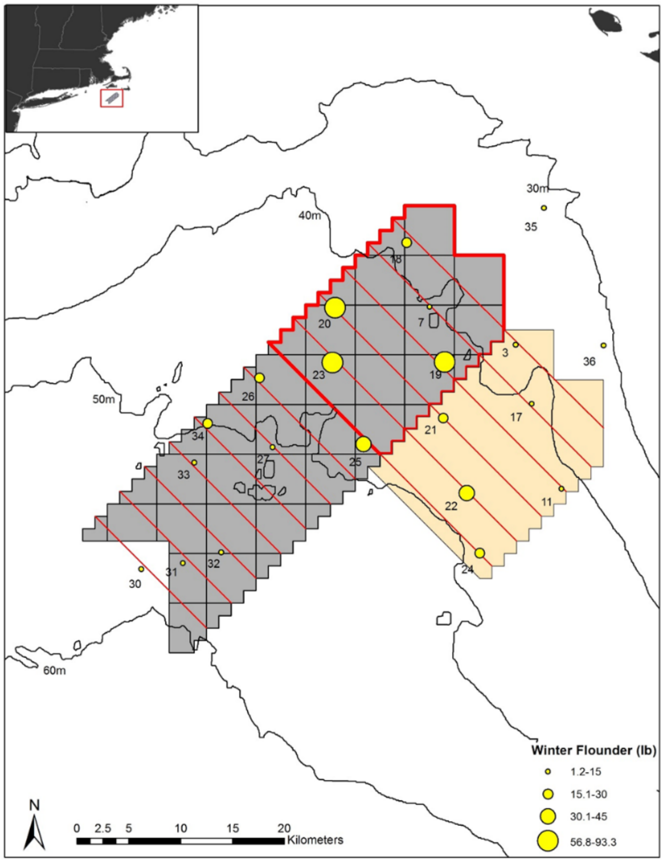

Figure A19. Distribution of winter flounder catches observed during the fall 2018 survey.

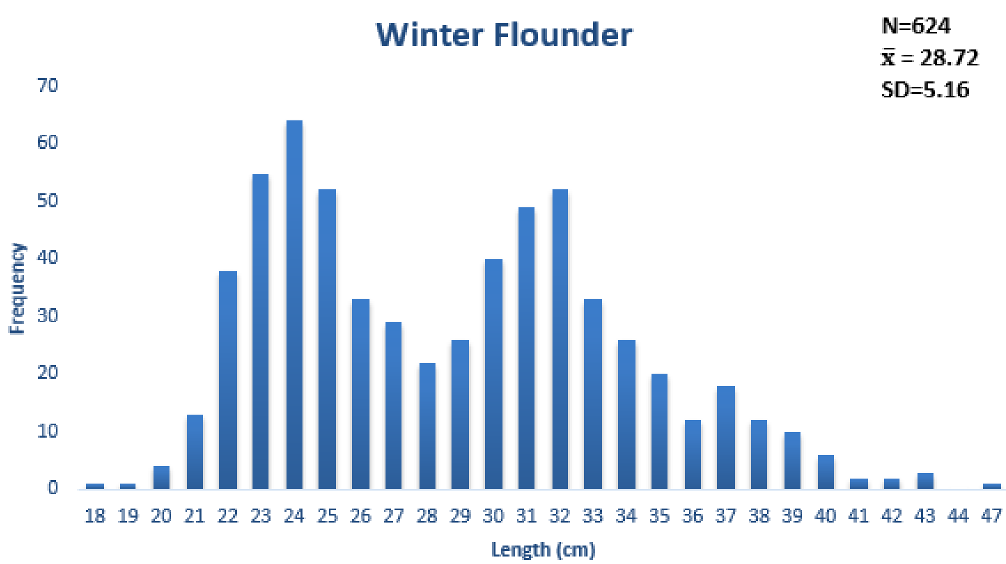

Figure A20. Length frequency distribution of winter flounder observed during the fall 2018 survey.

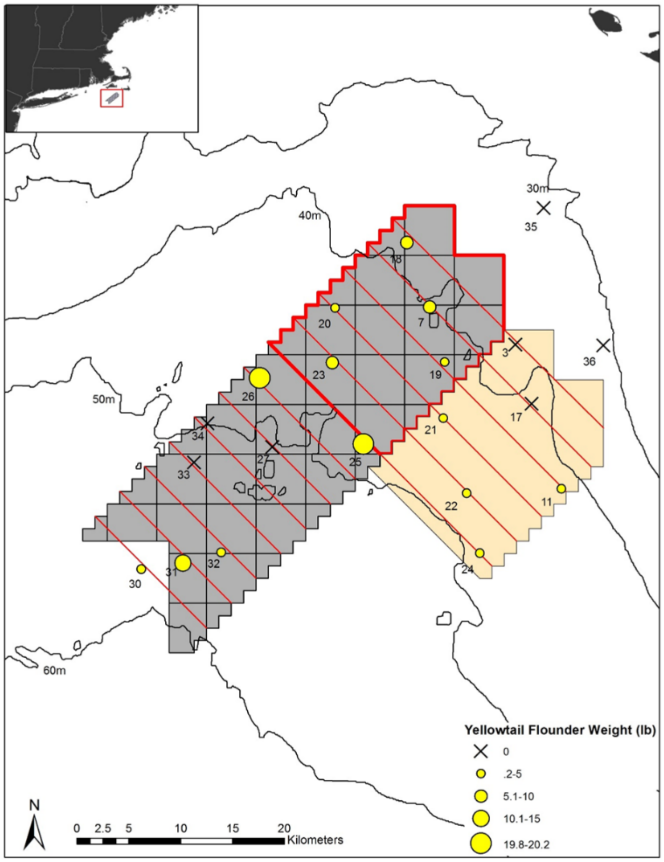

Figure A21. Distribution of yellowtail flounder catches observed during the fall 2018 survey.

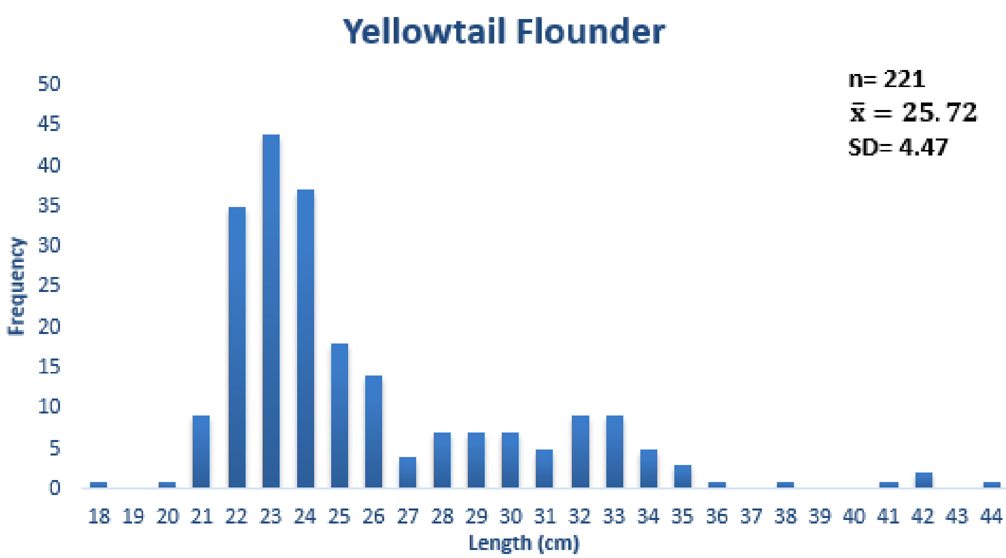

Figure A22. Length frequency distribution of winter flounder observed during the fall 2018 survey.

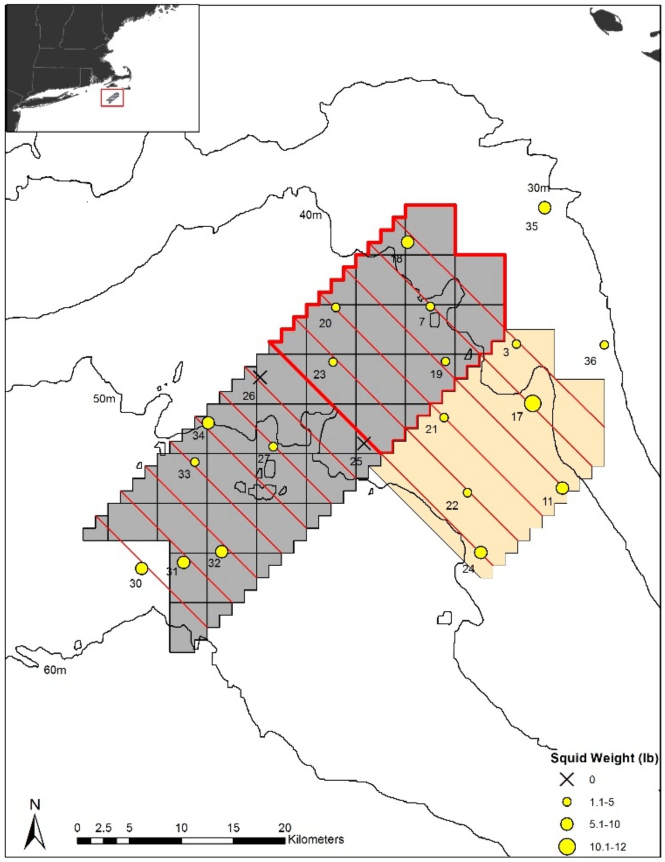

Figure A23. Distribution of squid catches observed during the fall 2018 survey.

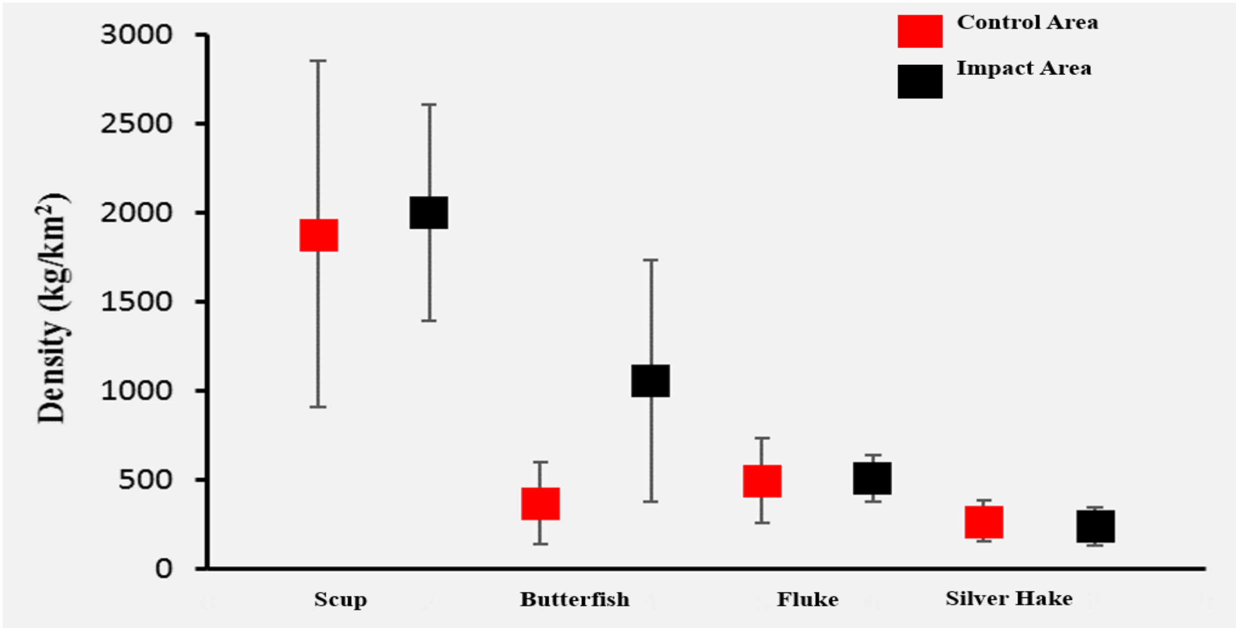

Figure A24. Mean density (kg/km^2) and standard error of scup, butterfish, fluke, and silver hake in control and development (Impact) areas.

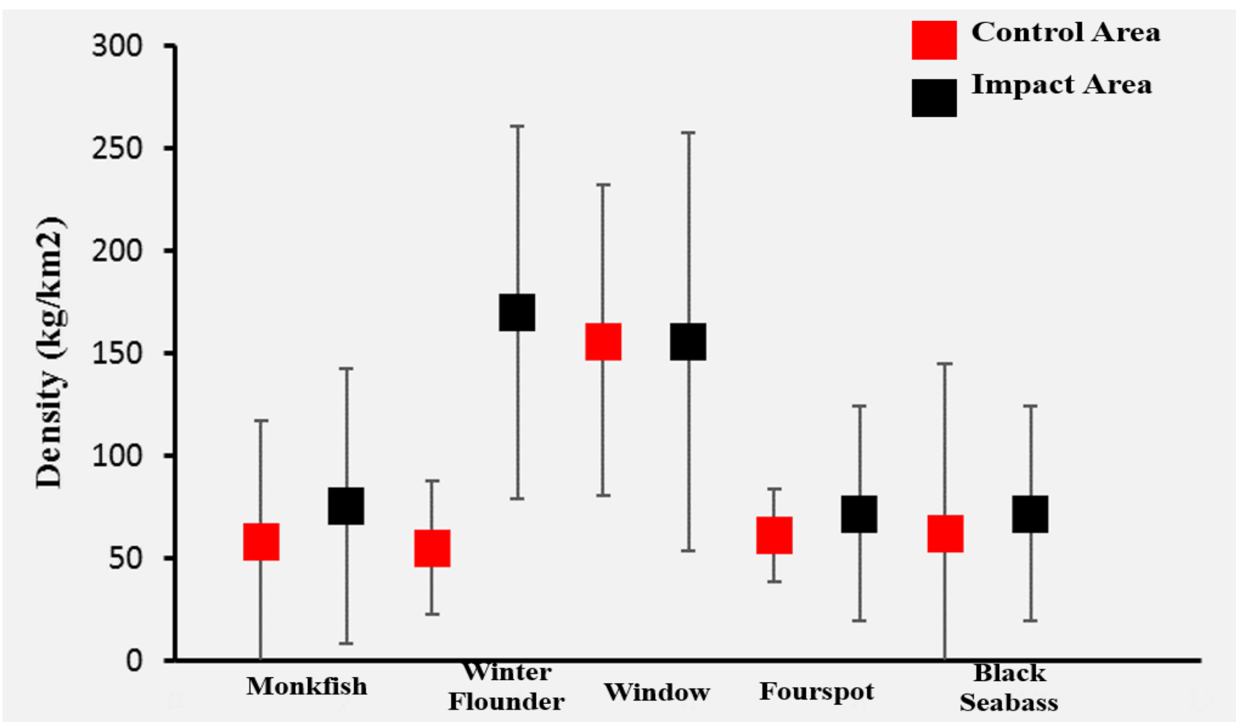

Figure A25. Mean density (kg/km^2) and standard error of monkfish, winter flounder, windowpane flounder, fourspot flounder, and black seabass in control and impact areas.

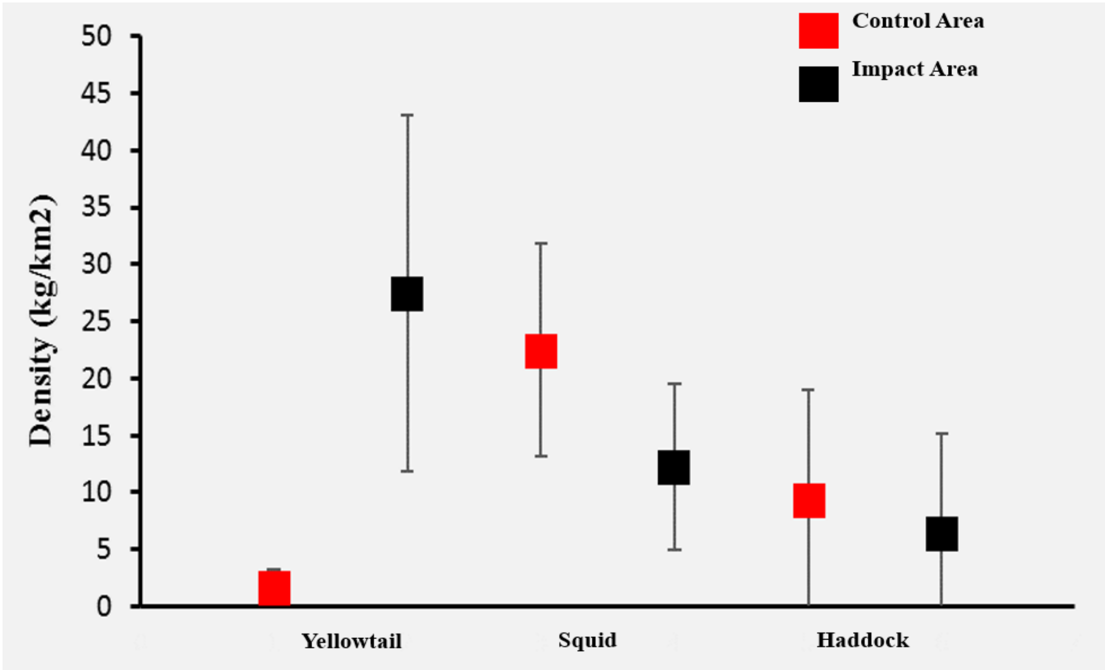

Figure A26. Mean density (kg/km^2) and standard error of yellowtail, squid and haddock in control and development (Impact) areas.

References

1. Gunderson, Donald R. *Surveys of fisheries resources*. John Wiley & Sons, 1993.
2. Krebs, Charles J. *Ecological methodology*. New York: Harper & Row, 1989.

Appendix C. Literature Review

Habitat

Guida, V., A. Drohan, H. Welch, J. McHenry, D. Johnson, V. Kentner, J. Brink, D. Timmons, E. Estela-Gomez. (2017).**Habitat Mapping and Assessment of Northeast Wind Energy Areas**. Sterling, VA: US Department of the Interior, Bureau of Ocean Energy Management. OCS Study BOEM 2017-088. 312 p.

- The study assesses abiotic and biotic relationships that occur benthically for all eight proposed wind energy areas (WEAs) in MA, RIMA, NY, NJ, DE, MD, VA, and NC-KH. Data collected from the NOAA NEFSC (benthic mapping, benthic grabs, CTDs, and trawl surveys), WHOI (HabCam IV camera system), and the UMass Dartmouth SMAST (drop camera survey) were combined to characterize sediment types, water quality parameters, and identify present fauna in each WEA.

- Results (summaries of each WEA):
    - **Massachusetts (743,000 acres)**: The area is dominated by primarily sandy bottom that tapers into mud nearest the southern end and gravel in the northwest corner. A strong thermohaline tidal front is caused by the Nantucket Shoals. Sand shrimp and sand dollars comprise most of the benthic epifauna. The warm season dominant taxa are longfin squid, scup, spiny dogfish, while Atlantic herring were common during the cold season. Recommendations for species of concern regarding habitat disturbances include black sea bass, Atlantic cod, sea scallop, and ocean quahog.
    - **Rhode Island-Massachusetts (165,000 acres)**: The sediments in the area are primarily sandy, but turn to mud in the north end and a mix of sand, coble, and gravel in the center. The southern portion contains sand, mud, and gravel caused by glacial outwash. Sand shrimp and sand dollars comprise most of benthic epifauna. Little and winter skates dominated year-round catches. This was coupled with longfin squid, scup, and spiny dogfish being most abundant during the warm season and Atlantic herring, yellowtail flounder, and ocean pout during the cold season. Species of concern due to habitat disturbance include black sea bass, Atlantic cod, sea scallop, and ocean quahog.
    - **New York (79,000 acres)**: The sediments in this area are almost entirely sandy bottom, with sand shrimp and sand dollars comprising 97% of the benthic epifauna. Megafauna was placed in 71 taxa, 33 of which are managed fisheries. Little skate presence was dominant year-round. Longfin squid and sea scallop characterize summer catches, while mainly Atlantic herring are seen in winter. Species of concern regarding habitat disturbance include black sea bass, longfin squid egg mops, sea scallops, surf clam, and ocean quahog.
    - **New Jersey (344,000 acres)**: Sediments in this area are characterized mainly by a platform in the northern area, sand and gravel in the north and center, and a shelf valley with megaripples in the southern portion. Grab sampling showed mostly polychaetes, with sand shrimp, sand dollars, and dwarf warty sea slugs accounting for 96% of the epibenthic fauna. Atlantic croaker, longfin squid, and scup are the most abundant species in the warm season, while Atlantic herring, little skate, and spiny dogfish dominated the cold season. Considerations should be given to black sea bass, sea scallop, and surf clam regarding potential habitat disturbances.
    - **Delaware (96,000 acres):** Bottom topography is strongly influenced by tidal action stemming from Delaware Bay. This results in mega-ripples throughout the east and northwest portions of the lease. Sediments otherwise are primarily sandy with gravelly areas. An artificial reef of 1000acres lies in the center, while a blue mussel reef is located in the northwest corner.

Polychaetes dominated grab sample infauna, while blue mussels, longclaw hermit crabs, New England dog whelk snails, and sand dollars characterized epibenthic catches. Atlantic croaker, northern sea robin, and scup are the most abundant species in the warm season, while Atlantic herring, little skate, and spiny dogfish dominated the cold season. Species of concern regarding wind turbine construction and operation include black sea bass, sea scallop, and surf clam. A loss of mussel reef, artificial reef, stony corals, and sea whips as potential degradation of habitat was also noted.

- **Maryland (80,000 acres)**: Sediments in the area are mainly comprised of megaripples, sand, and gravel, with muddy portions located in the center and south. Grab samples were dominated by polychaetes, with epifauna consisting of mostly sand shrimp, New England dog whelk snails, and sand dollars. Warm season fish species with the highest occurrences are Atlantic croaker, weakfish, and spot, with the cold seasons producing little skate, spiny dogfish, and spotted hake. Habitat disturbances from construction will most likely impact black sea bass, sea scallop, and surf clam. This is in addition to sea whip habitat being made vulnerable.
- **Virginia (113,000 acres)**: Sediments in this site are primarily sandy but contain a muddy patch in the center and gravelly sand in the east. Grab sample infauna was dominated by polychaetes. Epifauna consisted of mainly sand shrimp, unclassified snails, and dwarf surf clams in March 2014, but switched to calico scallops, longclaw hermit crabs, New England dog whelk, and dwarf warty sea slugs in August 2015. Warm season megafauna is mainly characterized by black sea bass, scup, and northern sea robin. This changes to clearnose skate, spiny dogfish, and summer flounder in the cold seasons. Species susceptible to habitat impacts include black sea bass, longfin squid egg mops, sea scallop, ocean quahog, and surf clam.
- **North Carolina (122,000 acres)**: Sediments in this area are mainly sandy, but also include isolated patches of mud and gravel. Benthic infauna is dominated by polychaetes, while the sampled epifauna consisted of mainly sea scallops, sand shrimp, and calico scallops. Atlantic longfin squid are present year-round. Seasonal megafauna mainly includes spotted hake (warm season), clearnose skate, and spiny dogfish (cold season). Species of concern include black sea bass, sea scallop, and surf clam.

- Conclusions: 1) All areas contain relatively flat topography with sandy sediments that are highly mobile. Most salinity ranges at the sites were small, but temperatures demonstrated considerable variation throughout the year and are caused by frequent turnover events. 2) Fauna that inhabit the WEAs share many common attributes and taxa. Polychaete worms comprise most of the infauna, while epifauna consists mainly of sand shrimp, sand dollar, and a variety of snail and crab species. 3) Megafauna present in the areas show substantial seasonality. The ability of these animals to recognize disturbance and migrate quickly could be perceived as potential resistance to disturbance. 4) Black sea bass were seen in all WEAs and Atlantic cod in the MA and RIMA. Species of concern due to lack of mobility include sea scallops (all WEAs), surf clams (all but RIMA), ocean quahogs (all but DE), and longfin squid egg mops (NY and VA).

Causon, P. and Gill, A. B. (2018). **Linking ecosystem services with epibenthic biodiversity change following installation of offshore wind farms**. Environmental Science & Policy. 89. 340-347. 10.1016/j.envsci.2018.08.013.

- This review aims to consolidate various studies that address and link habitat modification, benthic ecosystem dynamics, and biodiversity changes to the development of offshore wind farms.

- Results: 1) The introduction of hard substrate increases the complexity of the seabed. This translates into increased opportunities for fast-colonizing epibenthic organisms that associate with the newly installed structure. However, several studies indicate that epibenthic species living in artificial reefs differ from those found in natural reefs and substrates. Fish, such as Atlantic cod, have also been noted to aggregate around artificial structure. Habitat changes associated with a single turbine are likely minor, but cumulative impacts of many turbines across a large scale are uncertain. 2) Post-immersion of the turbines, dissolved macromolecules immediately colonize the new structure. Within hours, microscopic eukaryotes (diatoms, fungi, bacteria, etc.) form biofilms on the surface to entice colonization by other like-species. Organisms known to colonize platforms do so through a pattern of zonation that is dependent on depth and assemblages vary with structure type and mobility. Algae tend to be more abundant on fixed substrates, whereas barnacles, bryozoans, and sponges characterize more mobile substrata. In addition, some species settle preferentially on surfaces positioned in a specific orientation. This would make jacket foundations more suitable for related species than monopiles due to the difference in surface area. 3) The reef effects created by wind turbine structure can be linked to ecosystem services. Fecal deposition by epibenthic organisms can enrich surrounding sediments. Likewise, bioturbation by benthic infauna around the site resuspend inorganic material, making it available to primary producers. Higher chlorophyll-a concentrations were noted in closer proximities to wind farms in comparison to surface waters overlaying sandy sediments. This has potential to support secondary habitat created by mussels and increase opportunity for feeding and shelter by more mobile species at higher trophic levels.

- Conclusions: 1) Linking changes in biodiversity because of turbine development with ecosystem services highlights possible positive impacts to hard structure related community assemblages. As offshore wind increases expansion, there is potential for large scale adjustments to marine ecosystems through the installment of new, hard structure.

Invertebrates

HDR. (2017). **Benthic Monitoring during Wind Turbine Installation and Operation at the Block Island Wind Farm, Rhode Island**. Final Report to the U.S. Department of the Interior, Bureau of Ocean Energy Management, Office of Renewable Energy Programs. OCS Study BOEM 2018-047

- Sediments from turbines 1, 3, 5 and three control stations at the Block Island wind farm site were grab sampled. This was coupled with underwater video recordings that were taken at the time of sampling. Stratified random sampling of the area took place in winters 2016 and 2017. The study aimed to understand localized changes to macrofauna abundance, richness, assemblage structure, and diversity caused by the presence of five newly constructed wind turbines in the area. Abiotic factors such as sediment classification and organic carbon content were also considered.

- Results: 1) Aside from turbine 1 which contained the highest fractions of fine-medium sand, all other sites showed high fractions of coarse substrate types (sand, coble, and gravel). No significant differences were found when comparing the turbine areas to the control sites. 2) No difference in organic carbon content was demonstrated between the turbine and control sites. 3) There were no notable differences in macrofauna assemblage between all sites. Benthic community structure is mainly dominated by polychaete worms and crustaceans at both sites; abundances only differed between turbines 3 and 5.

- Conclusions: 1) Sediment characterization, organic carbon, and macrofauna communities were found to be homogenous between the turbine and control sites. No sign of biotic or abiotic changes at variable distances were detected due to the presence of the five wind turbines. These sites will continue to be monitored long term, as changes in these parameters may take longer to manifest.

Degraer, S., Brabant, R. & Rumes, B., (Eds.) (2012). Offshore wind farms in the Belgian part of the North Sea: Heading for an understanding of environmental impacts. Royal Belgian Institute of Natural Sciences, Management Unit of the North Sea Mathematical Models, Marine ecosystem management unit. 155 pp. + annexes.

Kerckhof, F., Rumes, B., Norro, A., Houziaux, J., & Degraer, S. (2012). **Chapter 3 A comparison of the first stages of biofouling in two offshore wind farms in the Belgian part of the North Sea**. *Offshore Wind Farms in the Belgian Part of the North Sea: Heading for an Understanding of Environmental Impacts*, 17-39.

- Species composition and ecological succession of biofouling in the subtidal zone of the Thorntonbank and Bligh Bank wind farms were compared during this study. The Thorntonbank windfarm was first sub-sampled in summer 2008 (2 gravity-based foundation turbines) while the Bligh Bank windfarm was examined in winter 2010 (3 steel monopile turbines). Seasonal sampling continued until fall 2011. Divers were sent to systematically sample fouling organisms by scraping a sampling surface of .25m x .25m; collecting a total of 111 samples from 36 stations. The results were compared by assessing composition using time after installation.

- Results: 1) 50% of the total species observed were shared between both windfarm sites and the total composition were dominated by the amphipod *Jassa herdmani*. Other dominant species included starfish and various other amphipod species. 2) More mobile species exhibited seasonal variation between higher abundances in summer and lower abundances in winter. 3) High diversities of organisms were seen in each respective early settlement phase, despite installations happening at different times of the year. The highest species richness measured occurred during the first summers of both sites. 4) All recorded species are typical colonizers of man-made surfaces in Belgian waters. Below the infralittoral mussel layer was dominated by echinoderms, anemones, barnacles, hydroids, and tube worms. Few species were able to establish permanent populations. 5) Aside from the slipper limpet, no introduced species were observed in the permanently submerged portion of the foundations.

- Conclusions: 1) Concrete foundations may offer better settlement surface, but there is still too much variation seasonally to tell. This suggests the fouling communities found in each site are still immature. 2) Early assemblage occurs by important prey items and are needed to support larger fauna around the wind farm sites.

Krone, R., Dederer, G., Kanstinger, P., Krämer, P., Schneider, C., and Schmalenbach, I. (2017). **Mobile demersal megafauna at common offshore wind turbine foundations in the German Bight (North Sea) two years after deployment - increased production rate of Cancer pagurus**. Marine Environmental Research. 123. 53-61. 10.1016/j.marenvres.2016.11.011.

- Different foundation types (jacket, tripods, and monopiles) within two different wind farm sites were sampled by divers to determine the total abundances of *Cancer pagurus* and other benthic species. Comparisons of abundances occurred between animals found on the foundations and animals found on the sea floor. Three tripod and three jacket style foundations were examined in the Alpha Ventus wind farm, while four monopiles were investigated at the Riffgat wind farm site. Divers used transects to search 15 different stations on each turbine and animals were identified and measured in situ.

- Results: 1) Crustacean communities found in all three foundation types were dominated by *C. pagurus*, *Liocarcinus spp., and Pagurus berhardus*. *C. pagurus* abundance was 2-6 times lower at jackets and tripod sites compared to monopiles. 2) Distribution varied between foundation types. At the jackets, 50% of recorded *C. pagarus* occurred between both the sea floor and foundation. This is compared to 80% that were found at the sea floor of monopiles and 90% on the foundations of tripods. 3) Regardless of foundation type, the sea floor was always dominated by older and larger *C. pagarus*. Animals less than 2 years were found in much higher abundances at the foundations compared to the sea floor. 4) Jackets and tripods were dominated by similar soft-sediment associated fish and crustacean species.

- Conclusion: 1) The species present at monopile sites are associated with hard bottom habitats (likely due to scour protection) and the lack of soft-bottom species can be interpreted as habitat loss. 2) The presence of young *C. pagarus* could indicate a special attraction by crab larvae to the structure. 3) Sea floor and foundation sections contribute differently to *C. pagarus* total abundances of varying foundations. It was calculated that with the current ratio of foundation types, new habitat to support an additional 120% *C. pagarus* could be added during planned future developments.

Roach, M., Cohen, M., Forster, R., Revill, A. S., & Johnson, M. (2018). **The effects of temporary exclusion of activity due to wind farm construction on a lobster (Homarus gammarus) fishery suggests a potential management approach.** *ICES Journal of Marine Science, 75*(4), 1416-1426. doi:10.1093/icesjms/fsy006

- During two sampling events from June through September 2013 and 2015, the ecological short term, post-construction effects of the Westermost Rough offshore wind farm (OWF) on the European lobster were assessed. Completed in 2015, the 35 km^2 site consists of 35 6MW turbines with scour protection. A BACI style approach was used and 30 strings consisting of 30 traps were placed both in the impacted wind farm site and the adjacent control area. Fishing occurred the entire length of the study in the control site, but was halted for 20 months in 2014-2015 at the OWF site due to construction. The wind farm site opened again to fishing during the last 11 days of the second sampling event. Abundance, sex, condition, and egg stage of lobsters were recorded for each site. CPUE and LPUE were used to evaluate differences in catch sizes and rates. Overall, 720 strings were hauled at each pre-construction and 690 strings were hauled post-construction.

- Results: 1) The size and distribution of lobsters differed significantly between the two sampling events. A larger portion of lobsters at a size >100mm CL was observed in the OWF site in 2015 compared to 2013. A broader range of carapace lengths were also reported (39-126mm in 2015 and 56-114mm in 2013). The greatest difference in distributions occurred in lobsters ranging from 75-92mm. 2) After fishing reopened, a decline in the proportion of lobsters greater than the minimum landing size (MLS) of 87mm were noted in both the OWF and control area, but a greater proportion of lobsters above the MLS were present in the OWF. 3) Sampling in 2013 yielded 6051 lobsters, while sampling in 2015 produced 8734 lobsters. CPUE increased significantly in both sites in 2015 and did not differ in the same year between sites. Mean CPUE was reduced significantly within the OWF site after reopening to fishing, but not in the control area. LPUE (landings per unit effort) were greater in both the OWF area and the OWF compared to the control site in both years sampled. The greatest ratio of LPUE:CPUE occurred during the time when the OWF site was closed to fishing.

- Conclusions: 1) The exclusion of fishing effort from the OWF site was found to have a direct effect on the size and distribution of the European lobster. This was demonstrated by a greater total number of lobsters after construction and a higher proportion of lobster above the MLS in 2015 compared to 2013. The addition of a scour zone could have increased available habitat in the area, but the differences in size were most likely attributed to the elimination of fishing during construction. The creation of a temporary "no take zone" during the construction phase led to an increase in higher quality lobsters when compared to baseline data and the control site. This could translate into management decisions of periodic closures. 2) The opening of the OWF site to fishing led to a rapid, short term increase in landings. This was not demonstrated in the control site open to fishing. A greater proportion of smaller lobsters existed in the control, so the larger lobsters residing in the OWF site may have repelled smaller lobsters from the area. 3). CPUE increased significantly for both sites in 2015. This was coupled with a significant increase in LPUE of lobsters greater than the MLS of 87mm CL. CPUE was also reduced when fishing reopened in the OWF area compared to both the control site and the time when fishing was closed. The highest ratio of LPUE:CPUE is indicative of larger, marketable lobsters that were not exploited. 4) After the impact site was opened to fishing, exploitation rates returned to levels seen in the surrounding area and indicate only short term impacts to the local lobster size and distribution.

Bergman, M.J., Ubels, S.M., Duineveld, G. C. A, Meesters, E. W .G. (2014). **Effects of a 5-year trawling ban on the local benthic community in a wind farm in the Dutch coastal zone**, *ICES Journal of Marine Science*, Volume 72, Issue 3, P. 962–972, https://doi.org/10.1093/icesjms/fsu193

- During the period between 2007 and 2011 a trawling ban was instituted within the Windpark Egmond aan Zee (OWEZ) designation area, but not the in adjacent reference areas. Baseline data was collected pre-construction in 2007 through another study which utilized box corers to evaluate grain size, mud content, and fauna. Fauna was further sampled using a "Triple D" style benthic dredge. A 9km^2 area within the wind farm was sampled and compared to six 2.2-4.4km^2 reference areas. Comparisons were made between the two sampling events and areas to evaluate the absence of bottom trawling on the benthic community.

- Results: 1) Box core data from 2011 suggests the OWEZ area fits well in the context of the reference areas. Species abundance in the OWEZ did not differ significantly from the reference sites, with 18 species accounting for 90% of the total abundance. 2) Sampling with the "Triple D" dredge in 2011 showed some minor variations between the reference areas, but overall there was no significant difference between all sites evaluated. Additionally, 15 species combined to comprise 90% of the total abundance. 3) There were no significant differences in species abundance upon comparing the OWEZ and reference sites between the years 2007 and 2011.

- Conclusions: 1) The positive influence of a five-year closure to fisheries on species abundance was not able to be demonstrated in this case. The possible benefit to bivalves could have been dampened by larval reduction caused by a depleted stock, enhanced predation, or low plankton abundance. Additionally, beneficial impacts related to the removal of fisheries are usually only concluded for closures longer than five years. Studies less than five years that examine impacts of a no-take-zone on bivalves have often ended inconclusively. 2) Some patchiness in abundance existed within the sites and positively correlates with decreased medium grain size and higher overall mud content.

Collie, J.S. and King, J.W. (2016). **Spatial and Temporal Distributions of Lobsters and Crabs in the Rhode Island Massachusetts Wind Energy Area.** US Dept. of the Interior, Bureau of Ocean

Energy Management, Atlantic OCS Region, Sterling, Virginia. OCS Study BOEM BOEM 2016-073. 48 pp.

- This study establishes ventless trap protocol to assess American lobster abundance and distribution within the RI/MA WEA while utilizing a BACI style approach. The survey occurred in both 2014 and 2015 and ran for the two-year duration to provide a baseline assessment in preparation of wind farm construction to be held in the area. Based on input from the lobster industry, the seasonal and spatial patterns of lobsters and other bycaught species were examined using a stratified random design by dividing the lease area into 24 lease blocks. Five aliquots (1/16 of a lease block) were randomly selected from each block. A single aliquot was then randomly chosen and held to be sampled throughout the entire year. New sampling stations were chosen for each year. The design was consistent with ASMFC protocols and utilized ten-pot trawls (six ventless and four vented). Eight trawls in a given portion of the area were designated to each commercial boat (three total) to sample four days per month. Detailed biological sampling was performed on lobsters, with bycaught species being subsampled. Physical environmental parameters were recorded and grab samples were coupled with side-scan sonar to classify habitat type. A pilot tagging study was also initiated in 2015 to examine the movement of lobsters within the leased space. Individually numbered cable ties were attached around the "elbow" of 300 post-molt lobsters

- Results: 1) Medium-coarse sand are present throughout the study area, while soft sediments are found in the more Northern, deeper aliquots. Boulders on sand were found in the Southwest and Eastern aliquots. Transition zones occur in the two central and eastern aliquots. 2) Lobster abundance was highest in the Northeast lease block in 2014, but was more evenly distributed in 2015. In general, lobster abundance was higher on the Eastern portion of the lease areas in both years. 2) In both years, lobster catches were 85% female in May, shifting towards a more equal sex ratio in the following months. The proportion of females with eggs was also the highest in May and declined to a minimum in August. This rose again to 26% in October of both years. 3) The proportion of animals with shell disease was overall low when compared to more inshore surveys. Percentage of lobsters with shell disease was highest in May and June of both years and fell below 10% in late summer due to molting. The highest incidence of severe shell disease occurred in the more near-shore sites. 4) Generalized additive models (GAMs) were created to explain relationships between space, time, and lobster abundance. The model was able to explain 61.8% of deviance in lobster counts based the independent variables habitat type, depth, and temperature. Lobsters were most abundant in the transition zone. Abundance was shown to rapidly increase with water temperature up to 14^{o}C. Depth had a small effect on abundance, but depths within the lease area do not greatly vary. The highest abundances were noted in the Northeast lease blocks, while the lowest was observed in the Southwest corners. 5) The most commonly bycaught species were Jonah crab, rock crab, red hake, and black sea bass. The Jonah crabs were subsampled due to their importance in a new, emerging fishery. Jonah crab catches were highest in the middle of the lease, with male catch rates being consistent throughout the year. Female abundance and the proportion of females with eggs were highest after May and contributed more to catch variations. Overall, abundances were highest in September and lowest in May and June. 6). The pilot tagging study produced a higher than anticipated recapture rate of 13%. The majority of the lobsters were captured within 2 months and traveled less than 25km. Ten lobsters traveled less than 10km, with four traveling over 120km to the continental shelf.

- Conclusions: 1) This study sampled a broad range of lobsters and the occurrence of juveniles is suggestive of recruitment to the lease area. 2) The results of the survey remained consistent over the course of the two years. A low, overall occurrence of shell disease was demonstrated. Lobster abundances were greater on the eastern portion of the site, with emphasis on boulder and transition zone habitats. 3) Bottom temperature proved to be best correlated with lobster abundance. Optimal temperatures historically range from 12-18ºC, so the temperature increase up to 14ºC falls within the ideal range. 4) Tagged recapture locations were indicative of historically described migration patterns. Some remained in the area for several months, while others were caught along the continental shelf. 5) Jonah crabs were the most abundant species throughout the entire survey, with most ranging between 60-160mm carapace width and preferring softer and sandy substrates.

Griffin, R. A., Robinson, G. J., West, A., Gloyne-Phillips, I. T., & Unsworth, R. K. (2016). **Assessing Fish and Motile Fauna around Offshore Windfarms Using Stereo Baited Video**. *Plos One, 11*(3). doi:10.1371/journal.pone.0149701

- Mobile fauna at varying distances (up to 100m) from eight turbines and two reference sites in Walney Offshore Windfarm (WOWF) were sampled using two Baited Remote Underwater Video systems (BRUVs) in full daylight hours at one hour deployment intervals on 25 and 26 July 2014. Each steel monopile is 6.5m in diameter with a scour protection zone that extends to 20m. The BRUV recorded motile species relative abundance, diversity, and length compositions to classify individuals as adults or juveniles.

- Results: 1) 118 individuals from 14 (9 fish and 5 crustaceans) taxa in total were recorded during the sampling period. This included commercially important species such as the European lobster, Norwegian lobster, and edible crab. 2) Relative abundance fluctuated between 3 and 9 individuals per sample, with average across all sites being 5.9±0.4. The most abundant species were the angular crab, small-spotted catshark, and whiting. 3)Abundance did not vary significantly with increasing distance from the turbines. 4) Significant differences were found between assemblage composition and the reference sites and was caused by the presence of angular crab, small spotted catshark, European lobster, and Norway lobster. 5) European lobster and wo species of catshark were significantly more abundant in samples nearest the turbines, with the opposite being true for the Norwegian lobster. No affinity for turbine structure was found for whiting.

- Conclusions: 1) The low overall abundances of animals is thought to have limited the statistical power and scope of the survey. Turbidity and declining the declining status of fish populations in the Irish Sea are thought to have contributed to low survey numbers. 2) Species commonly associated with hard bottom habitat (European lobster, edible crab, and two species of catshark) were higher in relative abundance closer to the turbine and scour protection. Norwegian lobster and angular crab associate more with soft sediments and were highest in abundance outside the wind farm. 3) BRUV systems provide adequate assessment of motile fauna within wind farms and utilize non-invasive sampling techniques to quantify assemblages with affinity for turbine structure.

Fish

Degraer, S., Brabant, R. & Rumes, B., (Eds.) (2012). Offshore wind farms in the Belgian part of the North Sea: Heading for an understanding of environmental impacts. Royal Belgian Institute of Natural Sciences, Management Unit of the North Sea Mathematical Models, Marine ecosystem management unit. 155 pp. + annexes.

Vandendriessche, S., Derweduwen, J., & Hostens, K. (2012). **Chapter 5 Monitoring the effects of offshore wind farms on the epifauna and demersal fish fauna of soft-bottom sediments**. *Offshore Wind Farms in the Belgian Part of the North Sea: Heading for an Understanding of Environmental Impacts,* 55-71.

- A total of 12 stations were examined within the Bligh Bank wind farm concession and reference areas. Abundance and diversity differences in benthopelagic, demersal, and epibenthic species present pre-construction (2008-2010) and post-construction (2011) were recorded. The study looked at two sources of change: impacts caused by the presence of wind turbines and fringe effects near the wind farm. The only comparisons came from August and was a result of inconsistent sampling during other times of year.
    - The sampled areas were separated into sandbank top and sandbank gullies. The designations fit depth contours present in the area and samples were collected using a shrimp trawl.

- Results-**Sandbank top**: 1) No benthopelagic fish occurred at the impact stations and low densities were noted at the reference stations. 2) Lower densities of demersal fish at the impact stations were present compared to the reference sites. Overall, there were fewer large turbot, no plaice less than 20 cm, and a shift in reticulated dragonet size classes. 3) Epibenthic biomass greatly increased at impact stations after being stable throughout 2008-2010. This coincided with diversity differences in echinoderms and hermit crabs between the impact and reference stations.
- Results-**Sandbank gullies**: 1) Total density impacts were less outspoken in gullies and a difference in species richness was not concluded. 2) Still, higher densities in lesser weaver, common starfish, and urchin were noted at the impact sites compared to the reference sites. 3) Lower densities of plaice at both impact and fringe areas were observed compared to reference stations. 4) Dab older than one year were scarce at impact stations.

- Conclusions: 1) In general, a decrease in demersal fish and an increase in epibenthic species were observed. No impacts could be directly linked to change in activities.

Degraer, S., Brabant, R. & Rumes, B., (Eds.) (2012). Offshore wind farms in the Belgian part of the North Sea: Heading for an understanding of environmental impacts. Royal Belgian Institute of Natural Sciences, Management Unit of the North Sea Mathematical Models, Marine ecosystem management unit. 155 pp. + annexes.

Derweduwen, J., Vandendriessche, S., Willems, T., & Hostens, K. (2012). **Chapter 6**: **The diet of demersal and semi-pelagic fish in the Thortonbank wind farm: Tracing changes using stomach analyses data**. *Offshore Wind Farms in the Belgian Part of the North Sea: Heading for an Understanding of Environmental Impacts,* 73-84.

- In Spring 2009 and Autumn 2010, four stations were sampled to compare differences between impact, fringe, and reference stations throughout the Thorntonbank Windfarm. The stomach contents of several different species were analyzed. This study was unable to sample all impact stations. Comparisons could only be made between the fringe and reference sites for some species (based on number of samples). The stomach contents of dab, solenette, dragonette, lesser weever, whiting, and horse mackerel were examined to identify changes in feeding patterns to determine: If the presence of the wind farm is affecting the diet of fish and if any fringe effects exist with regard to diet composition of animals in the reference area. A Fullness Index was created to indicate how “full” the fish were between each site. The diet composition was expressed in percentages and length frequencies were conducted to categorize size classes of each species.

- Results: 1) The diet of dab strongly varied between impact sites (mainly swimming crabs and amphipods) and reference sites (primarily mysids). 2) No uniform diet was determined for solenette as the composition percentages varied between length categories. 3) The stomach content of whiting was similar between fringe and reference sites, but whiting at fringe sites had fuller stomachs. 4) Lesser weever had fuller stomachs closer to the windfarm.

- Conclusions: 1) Fish in closer proximity to the windfarm site had fuller stomachs, suggesting fish closer to wind farms are eating more. However, a significant difference between fringe and reference stations was not found and a link to the presence of the wind farm could not be determined.

De Troch, M., Reubens, J.T., Heirman, E., Degraer, S., & Vincx, M., (2013). **Energy profiling of demersal fish: A case-study in wind farm artificial reefs.** Marine environmental research. 92. 10.1016/j.marenvres.2013.10.001.

- In autumn 2011, juvenile Atlantic cod and pouting were caught by conventional rod and reel at 1-10m distances from the scour layer of turbines within the Thorntonbank wind farm. Muscle and liver tissue samples were taken from ten of each species and sampled for carbohydrate, lipid, and protein content. Energy budgets were also calculated based on both available and consumed energy. Results were compared to sampling that occurred in spring 2011.

- Results: 1) As expected, lipid and carbohydrate content were highest in the livers of both species. Protein content was highest in muscle tissue. 2) Lipid storage in the livers of both species were considerably higher in fall than in spring. 3) Energy consumption in cod showed no difference between seasons with pouting energy consumption being much higher in autumn. 4) Food intake was greater than the energy required to maintain normal metabolic rates.

- Conclusions: 1) Normal metabolic requirements were met, so sufficient energy was left for growth and reproduction. Acoustic telemetry from previous studies have shown wind farm artificial reefs as high residency sites for Atlantic cod. 2) These energy levels demonstrated by both species show no indication of competition for food sources. Energy profiling supports the statement that wind farms are suitable feeding grounds for both species.

Reubens, J.T., Braeckman, U., Vanaverbeke, J., Van Colen, C., Degraer, S., Vincx, M. (2013). **Aggregation at windmill artificial reefs: CPUE of Atlantic cod (Gadus morhua) and pouting (Trisopterus luscus) at different habitats in the Belgian part of the North Sea**, Fisheries Research, Volume 139, Pages 28-34, ISSN 01657836, https://doi.org/10.1016/j.fishres.2012.10.011.

- Overall, six turbines (with scour protection) within Thorntonbank the wind farm, two shipwrecks, and two sandy substrate locations in the Belgian portion of the North Sea were sampled using conventional hooks and lines. This was to investigate relative abundances of Atlantic cod and pouting. The sampling occurred from January 2009 through December 2011 and the results from each habitat, month, and year were compared.

- Results: 1) More Atlantic Cod and pouting were caught at the wind turbines than any other site. The only significant difference between years took place in the wind turbine area. Atlantic cod catch was significantly lower in 2009 compared to the following years. 2) CPUE was highest in both species from late spring through late autumn and lowest in the winter through early spring.

- Conclusion: 1) The low CPUE demonstrated in 2009 for Atlantic Cod was a product of the construction effect. The wind turbines had been installed under a year at the start of the study. The addition of the turbines (combined with increased catch) is interpreted as a change in habitat type. 2) High CPUE in summer and low CPUE in winter is attributed to the life history characteristics of both species. 3) Highest relative abundances were seen in the wind farm site; indicating an aggregation effect.

Winter, H.V., Aarts, G. and Van Keeken, O.A. (2010) **Residence Time and Behaviour of Sole and Cod in the Offshore Wind Farm Egmond aan Zee (OWEZ**). IMARES, Wageningen.

- Over the course of nine months in 2007, sole and Atlantic cod were tagged and tracked to assess the behavior of these target species in response to the OWEZ wind farm operation in the southern portion of the North Sea. To accomplish this, 1100 mark-recapture tags were applied to sole to assess return rates and telemetry tags were placed in cod (47 individuals) and sole (40 individuals) around the wind farm to measure respective residence times. All mark-recapture tagging for sole occurred equally in impact and reference areas telemetric receivers were placed on 16/36 monopile foundations.

- Results: 1) Sole use the southern areas of the North Sea at different scales throughout the seasons studied. There was no difference in return rates for groups of sole tagged inside the wind farm when compared to the reference area. 2) 55% of sole with telemetry tags were detected for only a single day within the wind farm post-tagging. No evidence exists to support attraction to the monopiles, as the telemetry data describes random use of the area by sole. 3) Patterns in cod were highly variable, with usage ranging from a few days (30% of tagged cod) to the entire length of the nine-month study (15% of tagged cod). The average rates of detection for more resident fish were much higher than expected and suggests non-random movement. Rapid movements from one receiver imply small scale movements in the form of diurnal migration. Additionally, the length distribution of the tagged cod ranged from 24-47cm. Based on previous studies, this is indicative of the tagged cod group consisting of mainly juveniles.

- Conclusions: 1). Sole movement occurs at scales greater than the OWEZ, with some using the area for a few weeks during the growing season. Due to the spatial scale, no indication of large-scale avoidance was detected. 2). Behavior of Atlantic cod in the wind farm area ranges from very mobile to very resident. A few explanations were offered as to why the entire tagging effort consisted of juveniles; no conclusions could be drawn.

Stenberg, C., Støttrup, J.G., Deurs, M., Berg, C.W., Dinesen, G., Mosegaard, H., & Grome, T. M., and Leonhard, S. B. (2015). **Long-term effects of an offshore wind farm in the North Sea on fish communities**. Marine Ecology Progress Series. 528. 257–265. 10.3354/meps11261.

- The results from this study assess long term effects on fish abundance and distribution in relation to the Horns Rev wind farm established in 2002.   Baseline data was collected in September through October 2001 and compared to post-construction data collected eight years later in September 2009. In both instances, gillnet panels of varying mesh sizes were deployed (5 strings of 12 panels) at three different turbines and one control area. They were placed at increasing distance from the turbine structure to collect data on demersal (DEM), pelagic (PEL), and rocky (ROC) habitat related fishes.

- Results: 1) Whiting, sand eels, and dab comprised 76-88% of the total catches and were excluded from the ROC, DEM, and PEL groups. Prior to construction, catch rates were 4x higher in the control area compared to the impact site. Post-construction, abundance in the control area significantly decreased. This caused fish abundance at the control and impact to become similar to each other. 2) The overall catches mostly contained fish that were less than 30cm in length. Due to low catch numbers, length distributions could only be made for DEM species. No statistical difference was observed in fish lengths between the control and impact sites, in addition to the before and after periods. 3) Few fishes in the ROC and PEL groups were caught both before and after. This caused the data to be insufficient for analysis. The PEL group saw a shift from horse mackerel in the baseline assessment to horse mackerel and herring. The ROC group shifted from rock gunnels being the most abundant to goldsinny wrasse and pouting. 3) Distribution patterns in relation to turbine affinity were only significant for whiting and the ROC group. 4) There was no significant effect of the OWF on species diversity.

- Conclusions: 1) The decrease in abundance to the control site post-construction is characterized by the decline in whiting, hooknose, dover sole, and plaice. However, cod abundance increased several-fold. The decrease in total catch demonstrated at the control site coupled with the steady level at the impact site suggests a positive effect on fish abundance that mainly exist close to the turbines. This could be explained by the refugium effect, but fishing pressure in the area was low during the study. 2) The significant decrease in whiting abundance reflects the general decline of the North Sea stock. 3) The OWF had no effect on dab and sand eel, but the shift from mainly flat fishes to round fishes in the DEM group could be interpreted as introduction of new hard structure.

Electromagnetic Fields

CMACS (2003). **A baseline assessment of electromagnetic fields generated by offshore windfarm cables.** COWRIE Report EMF - 01-2002 66

- The Centre for Marine and Coastal Studies at the University of Liverpool was commissioned to examine likely electromagnetic fields (EMFs) produced by wind farm cables, develop monitoring and mitigation measures, and connect the results to future impacts to electrosensitive species. The group used two models to evaluate induced electric and magnetic fields of an industry standard three-core 132kV XLPE sub-sea power cable buried 1m beneath the seabed. The results produced by the model were compared to in-situ measurements of power cables (located in Liverpool) by two electric field sensors.

- Results: 1) Perfect shielding (grounded conductor sheathes) of the cable does not directly generate an electric field, but still creates a magnetic field that induces an EMF within the detectable ranges of elasmobranchs. 2) The model predicted imperfect shielding showed leakage of the electric field, but this is insignificant in comparison to the electric field generated by the magnetic field. 3) Cable burial at 1m was shown to be ineffective in dampening magnetic fields, but likely provides mitigation to more sensitive fish species. 4) Reduction in EMF was achieved by simulating materials of high conductivity and high permeability. 5) Measurements taken in-situ closely matched the model's predictions and therefore validate the model.

- Conclusions: 1) Industry standard three-core power cables will generate electric fields. The model predicted electric field output of 91μV/m in seawater above a cable buried at 1m. 2) This level is detectable by elasmobranchs and will likely induce a reaction. In-situ measurements were also within the detectable range of elasmobranchs. 3) Highly conductive and highly permeable material can effectively reduce electric fields; potentially minimizing attraction or avoidance reactions by elasmobranchs

Westerberg, H., and Lagenfelt, I. (2008). "Sub-Sea Power Cables and the Migration Behaviour of the European Eel." **Sub-Sea Power Cables and the Migration Behaviour of the European Eel**, vol. 15, no. 5-6, pp. 369–375. Fisheries Management and Ecology, RapidX.

- Acoustic tags were placed on 60 European eels in the Baltic Sea during eel migration season in October 2006 to test the effects of a sub-sea AC power cable. Subsequent receivers were installed at four transect sites (3-4km apart) for three weeks. The north and south transects had no overlap with the power cables, while the middle two transects were situated on either side of the cable. The cable is exposed in all locations except for the intertidal zone and the amperage ranged from 140 through 300 A during the course of the study. The tagged eels were released 7km north of the cable and swimming speeds across the transects was calculated by accounting for current advection, temperature, and salinity stratifications.

- Results: 1) Overall, 46/60 eels gave complete records of crossing through all four transects. Significant differences in swimming speeds occurred in animals crossing the middle transects on either side of the cable, but not when traversing over the north and south transects. 2) Swimming speeds across the cable were slowest at times of higher amperage, but the difference was not significant.

- Conclusions: 1) There were no alternative factors besides the presence of the cable that could have contributed to the slower swimming speeds seen around the cable. 2) No evidence exists to support migration obstruction by the cables, as the reduced swimming speeds translate to a 40-minute delay over a 7000km migration. 3) Other magnetic field-oriented fish species may react differently to the stimulus.

  Kavet, R., Wyman, M. T., Klimley, A. P., and Vergara, X. (2016). **Assessment of Potential Impact of Electromagnetic Fields from Undersea Cable on Migratory Fish Behavior Period Covering: January 2014 - June 2016**. Electric Power Research Institute, OCS Study BOEM 2016-041.

- In 2011 a 200 kV, 400MW 85km undersea cable called the Trans Bay Cable (TBC) was activated in San Francisco Bay. Prior to installment (for another study), acoustic tags were placed on adult green sturgeon and Chinook salmon smolts to identify potential impacts to electrosensitive species. The receivers were located on bridges and secured to the ocean bottom. The current study aimed to assess any alterations to behavior, the migratory path of bony fishes, and the cable's possible restriction as an obstacle to movement. To address these questions, the magnetic fields of the cable were measured and modeled, the magnetic distortions caused by bridges and cables in the bay were measured, and the behavioral responses to the cables and bridges were evaluated and compared to data from a previous study.

- Results: 1) Magnetic field measurements fed into a regression model that analyzed anomalies and concluded the angle of the cable effects the magnitude of the magnetic field. The impacts associated with depth and load currents produced substantial variability in the model. Overall, small (<1000nT) were detectable continuously along the cable route. 2) The rate of change associated with magnetic field anomalies was higher near the cables than at the surface. The EMF anomalies associated with bridges were far larger than those produced by the cable, with the strength of the anomaly relatively uniform throughout the water column. Tagged Chinook salmon smolts and green sturgeon passed through each receiver array in significant numbers, as 95% of green sturgeon were detected during outbound migrations at the mouth of the bay. Smolts were less successful; 1025 smolts were detected entering the bay, but inbound detection success varied at different stages throughout the receiver array. 3) A 20% increase in proportion was detected in smolts crossing the cable (once activated) when compared to past years. However, an 11.1% overall decline in smolts exiting the bay was observed. Misdirection may have significantly increased migration time in smolts, but the cable activation was not significantly related to transit rate. An increase of 96.01 hours noted in sturgeon transit time throughout the entire system showed a significant, positive relationship with cable activity.

- Conclusions: 1) Twist angle, cable depth, and load current variables originating from the model are concurrent with expected direct observations of EMF anomalies along the cable. 2) Green sturgeon and Chinook salmon smolts are not deterred by magnetic anomalies produced by either bridges or undersea cables and a barrier effect is not created. The number of smolts varying with entry to the bay is consistent with previous studies. 3) Chinook salmon smolts may be attracted the undersea cable initially, while green sturgeon showed increased travel time for outbound migrations but decreased for outbound movement. Overall, the cable activation did not impact migration success.

Putman, N. F., Verley, P., Endres, C. S., & Lohmann, K. J. (2015). **Magnetic navigation behavior and the oceanic ecology of young loggerhead sea turtles**. *Journal of Experimental Biology, 218* (7), 1044-1050. doi:10.1242/jeb.109975

- Loggerhead hatchlings from Melbourne Beach, FL were collected (138 total) in July and August of 2007 and 2008. Each animal was exposed to a single, 18-minute orientation test via introduction of simulated magnetic displacements. The hatchlings were subjected to magnetic fields from one of five different points along the known migration route of young loggerhead turtles. Swimming orientation response was measured regarding the magnetic stimulus experienced by the animals. The results were input into an ocean circulation model to allow for further evaluation.

- Results: 1) Two out of the five magnetic field treatments elicited a significant difference in hatchling orientation when compared. Animals that were subjected to northern Portugal magnetic fields oriented themselves southward, while the magnetic field seen near Barbados revealed a northward swimming response.

- Conclusions: 1) The southward swimming of young loggerhead turtles is consistent with previous results in animals tested near Portugal. The Canary Current System likely causes this southward orientation in young turtles. If animals drift passively for long enough they will be placed in a region that is too cold for survival. 2) The northward orientation near Barbados likely increases the chances the animals enter the Antilles Current. The Antilles Current prospectively transports the animals to the North American coast, where juveniles are known to reside. 3) Why non-oriented swimming of animals in the other three magnetic fields is unknown but could explained by analysis of the ocean circulation model. The model did not reveal any clear survival risks associated with non-oriented swimming in those locations.

Hutchison, Z. L., Sigray, P., He, H., Gill, A .B., King, J., and Gibson, C. (2018). **Electromagnetic Field (EMF) Impacts on Elasmobranch (shark, rays, and skates) and American Lobster Movement and Migration from Direct Current Cables**. Sterling (VA): U.S. Department of the Interior, Bureau of Ocean Energy Management. OCS Study BOEM 2018-003.

i) **Field Surveys of the Cross Sound, Neptune, and Sea2shore Cables**

- The Cross Sound cable is a 330 MW, 300 kV, 40km (24 mile) HVDC (high voltage direct current) cable with a maximum electrical current of 1175 A that traverses Long Island Sound and is buried to a depth of 2m. The Neptune cable is a 660MW, 500kV, 105km (65 mile) HVDC cable that carries an electrical current of 1320 A. It connects Long Island to Sayerville, NJ and buried at depths between 1.2-1.6m. The Sea2shore cable is a 32km (20 mile), AC (alternating current) cable that connects the Block Island wind farm to the remainder of Rhode Island. A Swedish Electromagnetive Low-noise Apparatus (SEMLA) was towed at transects along each of the cable routes to assess the EMF deviations caused by the presence of the cables.

- Results: 1) When not delivering power, the Cross Sound Cable showed positive deviations of .18µT and negative deviations of .12µT. When power was being delivered, this changed from 3.79µT and 2.83µT, respectively. The highest deviations were seen in transect 7 and were 14.3µT and 18.7µT. 2) The Neptune Cable showed an average positive deviation of 6.8µT and an average negative deviation of 2.2µT. 3) The AC Sea2shore cable deviations ranged between .005µT and 3.1µT with the 60Hz harmonic field dominating all other harmonic measurements. 4) The HVDC cables also generated average AC magnetic fields of 0.04µT and 0.15µT for the Neptune and Cross Sound Cables, respectively.
- Conclusions: 1) The SEMLA is cost-effective and reliable method of surveying EMF anomalies along sub-sea cable routes. 2) The EMF peaks at the Cross Sound and Neptune Cables were higher than expected. 3) HVDC cables produced an AC magnetic field that is detectable hundreds of meters from the point source and could have biological implications. 4) AC cables producing AC magnetic fields, were on average 3x weaker than those generated by HVDC cable. The use of AC cables is likely to minimize biological implications.

ii) **Cable Electromagnetic Fields Simulation of the Cross-sound Cable**

- The EMF of the Cross Sound Cable was modeled using COMSOL to assess the effects of burial depth, geometry, materials used, and electrical current load on EMFs. The EMF of the Neptune Cable was also simulated to verify the model's capacity to scale up to large capacity HVDC cables.
- Conclusions: 1) The electrical field generated by the cable is perfectly contained within the cable, but the generated magnetic fields occur in the surrounding environment. 2) Deviations were dependent on burial depth, the distance between cables, and environmental parameters. Lower fluxes in EMF were associated with increased burial depth and EMF influence decreased with increased distance from the cable. 2) The COMSOL model was found to be a useful tool for modeling EMF in underwater HVDC cables.

iii) **Field Study to Detect the Effects of EMF on Marine Species**

- This portion of the report was developed to determine the potential biological implications of the sub-sea, Cross Sound Cable on key benthic species; the American lobster and little skate. A treatment site was selected along the Cross Sound Cable route (EMF of 65.5 µT), while a control site was selected based on site similarity and a lack of deviation from earth's natural magnetic field (51.3 µT). One enclosure containing American lobster was situated along the cable route, while the other was placed in the control area. Telemetry was used to assess 3-dimensional movements of species within the enclosure. Animals were released for 12-24 hours to examine total distance moved, height from the seabed, change in turning angles, and spatial distributions within the enclosure. After completion of either site, the animals in the cages were relocated to the opposite enclosure and the same measurements were then investigated. Relocation of the animals to the contrasting enclosure constituted 1 trial and was then accomplished for little skate as well. Overall, a total 13 lobster trials (n=20) and 8 skate trials (n=14) occurred.
- Results- **Lobster**: 1) Animals in the control enclosure traveled an average distance of 4.05km. This is compared to the treatment site that showed average movements of 3.76km. 2) Mean speeds were modeled with two different models using log transformed mean speeds. These yielded average speeds of 10.14 cm/s and 9.91 cm/s in the control site and 10.41cm/s and 10.18cm/s in the treatment sites. 3) The modeled heights from the seabed showed lobsters in the treatment were 14.17% closer to the seabed when compared to the control site. This was

determined to be significant. 4) Lobsters in the treatment enclosure made 16.23% fewer large turns than in the control when starting in the treatment. Lobsters that were moved from the control to treatment site showed a 34% higher proportion of large after being relocated. This was determined to be significant. 5) Spatially, the lobsters were most frequently recorded at the ends of each enclosure, but were found in the center of the treatment cage more often than in the control. When a time component was factored in, there was a statistical significance in distribution towards the center of both enclosures.

Little Skate: 1) Skates in the treatment enclosure traveled 93.02% further than animals in the control. This was more pronounced when the skates were exposed to the treatment before the control. When exposed to the control and then the treatment, this dropped to 22%. The distances in each "zone" of the cage also differed significantly and suggests the skates traveled further in zones with increased EMF. 2) Animals demonstrated faster overall swimming speeds at the second enclosure they were placed in. However, the difference was much larger (29.12%) when the animals were relocated to the treatment enclosure after the control when compared to the opposite scenario (2.96%). 3) Skates were on average, 35% closer to the seabed in the treatment enclosures. This was not associated with high or low EMF. 4) Animals in the treatment enclosure significantly made 38% more large turns than the control in "zone 2" of the cage and is possibly related to high EMF. 5) The distribution of little skates was not significant in either case, as the whole length of the enclosure was utilized. The addition of a time component showed skates spent more time in zones of high EMF at the treatment enclosure.

Conclusions: 1) Lobsters in the treatment enclosure were closer to the seabed and demonstrated a higher proportion of large turns; suggesting lobsters respond to EMF. 2) Stronger responses were elicited in little skate. Animals in the treatment enclosure traveled 20-93% further, at slower mean speeds, were closer to the seabed, and showed a higher proportion of large turns. 3) Behavioral responses in both movement and distribution occur in both American lobsters and skates when exposed to EMF from a HVDC sub-sea cable. However, it was not determined that EMF creates produces any barrier effects, as full use of the enclosures were made.

Sound

Mooney, T. A., Hanlon, R.T., Christensen-Dalsgaard, J., Madsen, P. T., Ketten, D. R., and Nachtigall, P. E. (2010). "**Sound Detection by the Longfin Squid (Loligo Pealeii) Studied with Auditory Evoked Potentials: Sensitivity to Low-Frequency Particle Motion and Not Pressure.**" *Journal of Experimental Biology*, Vol. 213, No. 21, p. 3748–3759., doi:10.1242/jeb.048348.

- The acoustic sensitivity and thresholds of longfin squid was examined using both sound field pressure and the acceleration of particle components at 30-10000Hz. Responses were assessed through Auditory Evoked Potential (AEPs). Electrodes were placed on various portions of the animal at different water temperatures to assess the statocyst's role in acoustic detection. A shaker table system was built to identify the effects of particle acceleration as a lone variable.

- Results: 1) Responses were elicited at 30-500Hz, with the lowest thresholds between 100-200Hz. 2) AEPs did not occur at any frequencies if the water temperature was less than 8ºC, the statocyst was ablated, or the electrodes were placed anywhere but the statocyst. 3) Longfin squid were unable to detect sound caused by pressure, but rather the acceleration and particle components of sound.

- Conclusions: 1) Longfin squid use statocysts to detect low frequency particle motion stimulus in a manner similar to the ears of most elasmobranch and teleost fishes. Low frequency particle motion flow extends to distances of around 4.8m at 100Hz.

Magnus, W. and Westerberg, H. (2005). **Hearing in fish and their reactions to sounds from offshore wind farms.** Marine Ecology - Progress Series, Vol. 288, p. 295-309.

*The authors consistently emphasized the cautious approach that should be taken when evaluating the context of the inputs and results. This is due to lack of previous knowledge and heavy reliance on assumptions.

- This paper is a review of current knowledge regarding the ability of fish to detect and react to sound in relation to offshore wind farms (OWF). Rooted in various studies, three species were selected based on varying detection capabilities to evaluate the potential reactions by each group. These potential reactions include the masking of acoustic signals, constant triggering of alarm responses, and temporary or permanent hearing damage by Atlantic salmon (hearing non-specialist), cod (hearing generalist), and goldfish (hearing specialist). Critical bands (perceived noise level) in fish are not widely determined, but some information exists for the species of interest. Using previous data on critical bands, the hearing and maximum detectable range for each species can be solved for. The authors noted a lack of existing data regarding how fish detect signals present in noise, directional hearing properties, real measurements of noise around turbines, few signal type and sound level relations, and known impacts to eggs, larvae, and juveniles. Matlab was used to relate detectable distance to the detectable bandwidth of the studied species at wind speeds of 8 and 13 $m\ s^{-1}$.

- Results: 1) At wind speeds of 8 $m\ s^{-1}$, the detection frequency produced was 100Hz in Atlantic salmon and 63 Hz in goldfish and cod. This could be detected by goldfish at 25km, cod at 13km, and Atlantic salmon at .4km. At speeds of 13 $m\ s^{-1}$, the detectable frequency produced was 100Hz in Atlantic salmon and 180Hz in goldfish and cod. This could be detected by goldfish at 15km, cod at 7km, and Atlantic salmon at .5km. 2) The noise produced at even 1m distance from the turbines is not enough to cause avoidance by salmon and eels. At frequencies under 20Hz fish are affected by acceleration rather than the pressure component of sound. Other studies show the maximum particle acceleration caused by turbines .5 $m\ s^{-1}$ for frequencies < 20Hz. The rate of decrease for this frequency is dependent of turbine structure type and water depth. 3) Noise levels are not sufficient enough to cause temporary or permanent hearing damage.

- Conclusions: 1) It is predicted that goldfish, cod, and Atlantic salmon can detect noise from wind turbines (<1.5 MW) at wind speeds of 8 and 13 $m\ s^{-1}$ up to distances of .4 and 25km, respectively. 2) Detections are a function of wind speed, turbine type, water depth, and substrate type. 3) Shipping produces higher intensity sounds than wind turbines, but comparison is difficult due to the transient nature of shipping. Few studies have examined long term effects on fish hearing by low intensity stimulus.

Degraer, S., Brabant, R. & Rumes, B., (Eds.) (2012). Offshore wind farms in the Belgian part of the North Sea: Heading for an understanding of environmental impacts. Royal Belgian Institute of Natural Sciences, Management Unit of the North Sea Mathematical Models, Marine ecosystem management unit. 155 pp. + annexes.
Haelters, J., Van Roy, W., Vigin, L., & Degraer, S. (2012). Chapter 9 **The effect of pile driving on harbour porpoises in Belgian waters**. *Offshore Wind Farms in the Belgian Part of the North Sea: Heading for an Understanding of Environmental Impacts*, 127-143.

- Impacts of pile driving during the Thorntonbank windfarm construction on harbor porpoise population were assessed using a BACI style analysis. Special attention was given to four periods in time; before and during two pile driving events in March and April 2011. Passive acoustic monitoring devices (PAM) were paired with aerial surveys to evaluate spatial and temporal abundances and distributions. Porpoise Detectors were used as PAM devices and were moored at 3 locations; 1 impact (100m from piling sites) and 2 reference stations located at distances of 4.5km and 22km from the windfarm, respectively. Aerial surveys (4 total) followed 13 transect lines 5km apart both before and during pile driving events. Impact modeling was applied to determine size and scope of these pile driving effects.

- Results: 1) Aerial surveys showed densities of 2.5 animals/km^2 before piling activities and 1.3 animals/km^2 during piling (on average). Distribution of harbor porpoise were uneven and occurred mainly in the Western portions of Belgian waters before piling. During piling densities remained highest in this area. Densities observed in a 10-20km radius were low and 0 observations were made inside the 10km radius of piling activities. 2) PAM results showed a negative trend in all stations over the course of the study. Slight recoveries occurred 12-14 hours after piling was completed at the impact stations but returned to 0 once piling disturbances returned. The decrease in harbor porpoise detection at the impact stations was determined to be statistically significant. 3) After 7 April, no acoustic detections at the impact site were made. These before and after results cannot be explained by gradual migration and are attributed to disturbance in the area. 4) The results from PAM and aerial surveys were consistent. Detection rates by passive monitoring dropped to zero immediately after pile driving began and densities did not recover during the period of spring piling activities. The 16 April aerial survey observed no harbor porpoises within a 20km radius of the piling site.

- Conclusions: 1) Pile driving at the Thorntonbank windfarm site repelled harbor porpoises from the piling site up to 20km.

Bailey, H., Senior, B., Simmons, D., Rusin, J., Picken, G., Thompson, P.M., (2010). **Assessing underwater noise levels during pile-driving at an offshore windfarm and its potential effects on marine mammals**, Marine Pollution Bulletin, Vol. 60, Issue 6, Pages 888-897, ISSN 0025-326X, doi.org/10.1016/j.marpolbul.2010.01.003.

- Two 5W turbines were installed near Moray Firth, Scotland in water with an average depth of 42m. Hydrophones were suspended 5m below sea level at “close” proximity to the piling site (100m-2km) and a “further” range of 500m throughout the distance at which the piling sound was indistinguishable background noise. The potential impacts caused by the increased acoustics were categorized based upon severity. No data values exist for permanent hearing damage in marine mammals, so the results were based on modified auditory thresholds.

- Results: 1) The pile driving event was detectable up to 70km from the site. 2) Permanent auditory damage in cetaceans and pinnipeds are likely to occur 5m and 20m, respectively. Temporary shifts in hearing are probable at 10-40m from piling activities for both pinnipeds and cetaceans.

- Conclusions: 1) The highest measurement (166db at 100m from the piling site) indicates that no permanent or temporary auditory damage is likely to occur outside of 100m. Marine Mammal Observers are required during piling through environmental protection laws to avoid these occurrences. This information is translatable to full-scale windfarm installations. 2) Auditory damage is unlikely at ranges greater than 100m, but pile driving was detected up to 70km from the site. Behavioral disturbances are more likely given the detectable range of pile driving. The study indicates strong avoidance behaviors at maximum ranges of 20km in harbor porpoises, 14km in pinnipeds, 50km in bottlenose dolphin, and 40km in minke whales.

Martin, B., Zeddies, D., MacDonnell, J., Vallarta, J., and Delarue, J. (2014). **Characterization and potential impacts of noise producing construction and operation activities on the Outer Continental Shelf: data synthesis**. U.S. Dept. of the Interior, Bureau of Ocean Energy Management, Gulf of Mexico OCS Region, New Orleans, LA. OCS Study BOEM 2014- 608. 84 p.

- From June 2010 through August 2011, acoustic devices were deployed in the areas leased in Nantucket Bay to Cape Wind and outside of Delaware Bay to Bluewater Wind. Ambient acoustic levels were monitored to determine baseline levels for each site. In addition to this, sounds projected by marine mammals in the areas were detected and classified.

- Results-**Delaware Bay**: Delphinids were the most commonly detected family of marine mammals. The occurrence of delphinids peaked in early May until mid-August. Fin whales had the highest cetacean detection and peaked throughout the fall and winter. Atlantic right whale and humpback whale calls were identified on a several occasions.
- Results- **Nantucket Sound**: Atlantic right whale calls were detected once throughout the study. The Cape Wind site mostly experienced acoustic noise produced by shipping disturbances and fish populations in the area.

- Conclusions: 1) Sufficient information was collected to develop an accurate baseline to use for comparison between ambient noise and noises demonstrated both during and post-construction. 2) Future developments of the Delaware bay site should consider Atlantic right, fin, and humpback whale migration through the area; focusing on the months ranging from January to March. 3) Marine mammal detection was essentially absent from the Nantucket Sound site.

Dow Piniak W. E., Eckert, S. A., Harms, C. A. and Stringer, E. M. (2012). **Underwater hearing sensitivity of the leatherback sea turtle (Dermochelys coriacea): Assessing the potential effect of anthropogenic noise.** U.S. Dept. of the Interior, Bureau of Ocean Energy Management, Headquarters, Herndon, VA. OCS Study BOEM 2012-01156. 35pp.

- Hearing thresholds in 23 newly hatched leatherback sea turtles from Matura Beach, Trinidad were exposed to sounds of varying frequencies both in and outside of water. Blood samples were taken from the turtles shortly after collection to allow for comparisons before and after exposure to the sound. These were necessary to measure the effects of required anesthesia and sedatives that allowed for the examinations of auditory responses. An amplified speaker subjected the animals to varying pressures and frequencies. Responsiveness was measured via needle electrodes placed on the animals.

- Results: 1) In air leatherback turtle hatchling were able to detect frequencies of 50-1600Hz (62dB), with a maximum sensitivity between 50 and 400Hz. 2) In water the hatchlings detected sounds at a range of 50-1200Hz (84dB), with a maximum sensitivity of 100-400Hz.

- Conclusions: 1) Leatherback sea turtle hatchlings hearing ranges overlap with sound produced by point sources such as pile driving, shipping, wind turbine operation, and sonar. Although unlikely at greater distances, a decrease in sensitivity caused by an increase in background noise reduces an animal's ability to monitor the acoustic environment. 2) The effects of anesthesia and sedatives on hearing sensitivity in turtles has not been explored. The results of this study align with similar studies; all agree and conclude that any negative effects are unlikely.

Rolland, R.M., Parks, S.E., Hunt, K.E., Castellote, M., Corkeron, P.J., Nowacek, D.P., Wasser, S.K., Kraus, S.D. (2012). **Evidence that ship noise increases stress in right whales,** *Proceedings of the Royal Society B: Biological Sciences*, 279 (1737), pp. 2363-2368.

- A four-year study from 2001-2005 on North Atlantic right whale stress levels caused by shipping noise was underway at the time of 11 September 2001 in the Right Whale Conservation Area of the Bay of Fundy. Fecal samples from right whales were collected and analyzed for metabolites reflective of adrenal glucocorticoid hormone (GC) levels before (114 samples) and after 9/11 (30 samples). GC metabolites in feces are a direct indicator of stress levels experienced by the animal; these hormones are released shortly after the stressor occurs. No known stressors (aside from ship noise) to the right whale population were present at that time. Acoustic recordings were compared with GC levels before and after 9/11 in 2001-2005, as shipping traffic was greatly reduced after 11 September 2001.

- Results: 1) A reduction in shipping noise was observed after 11 September 2001 when compared to the calculated baseline monitoring values. This translates to a significant decrease of 6dB and an overall reduction of noise in low-level frequencies ranging from 50-150Hz. 2) Sampled right whales exhibited significant declines in GC levels during this time.

- Conclusions: 1) This study is noted as being unrepeatable; given the small sample size of right whales present in the area before and after 11 September 2001. 2) This is the first evidence that exposure to low-frequency ship noise may be associated with chronic stress in North Atlantic right whales. 3) Chronic stress is very difficult to link to detrimental health effects in whales because controlled studies are not feasible. However, other tested vertebrates have shown that elevated GC levels are coupled with a decline in health.

Kraus, S.D., Leiter, S., Stone, K., Wikgren, B., Mayo, C., Hughes, P., Kenney, R. D., Clark, C.W., Rice, A. N., Estabrook, B. and Tielens, J. (2016). **Northeast Large Pelagic Survey Collaborative Aerial and Acoustic Surveys for Large Whales and Sea Turtles.** US Department of the Interior, Bureau of Ocean Energy Management, Sterling, Virginia. OCS Study BOEM 2016-054. 117 pp. + appendices.

- From October 2011 through June 2015, a study area that included the MA WEA and the RIMA WEA were both acoustically and aerially surveyed for the presence of various large whale and sea turtle species. Passive acoustic monitors were placed in nine different locations within the WEA's and marine mammal observers paired with cameras situated on the aircraft were used to identify whale and sea turtle species.

- Results: 1) North Atlantic right whale analysis showed consistent hot spots throughout both WEA's and the study areas. There was no significant variation throughout each year, as use patterns by right whales was always highest in the winter and spring months. The study identified 77 total individuals that used this habitat and calls were identified on 47% of the total study days. 2) Fin, humpback, sei, and sperm whales dominated spring and summer month usage by large cetaceans. 3) Loggerhead turtles were primarily seen in August and September and showed no variation between years. The lone year loggerhead turtles were detected in high numbers was 2012. Leatherback turtle use occurred in the Northeast edge of the MA WEA and portions of the study area each year during summer and autumn.

- Conclusions: 1) Acoustic data coupled with aerial surveys showed comparable trends in seasonality. Higher abundances seen in aerial surveys translated to more frequent acoustic detections. 2) The distribution of endangered large ceteceans were widespread throughout the study area in spring and summer months. 3) Pairing the 77 total right whales seen in this study with NMFS surveys during that time and area, yields 202 individuals in the study area; 41% of the remaining population. 4) This study, coupled with other tagging efforts suggest the NE portion of the MA WEA is important foraging habitat for leatherback turtles.

Cumulative Impacts

Lindeboom, H. J., Kouwenhoven, H. J., Bergman, M. J., Bouma, S., Brasseur, S., Daan, R., Fijn, R.C., Haan, D. de, Dirksen, S., Hal, R. van, Ris Lambers, R. Hillie, Hofstede, R. ter, Krijgsveld, K.L., Leopold, M., and Scheidat, M. (2011). **Short-term ecological effects of an offshore wind farm in the Dutch coastal zone; a compilation.** *Environmental Research Letters,6*(3), 035101. doi:10.1088/1748-9326/6/3/035101

- The study compares pre-construction baseline data collected in 2003 with data gathered shortly after the construction of the Windpark Egmond aan Zee (OWEZ) in the Netherlands. In total, the 108MW farm is comprised of 36 steel monopile turbines with a scour protection layer that has a diameter of 25m. Benthic organisms, fish, birds, and marine mammals were sampled using various methods to detect impacts throughout the years 2007-2009 in impact and reference areas. Benthic sampling utilized box corers, sieves (benthic infauna and sediment characterization), and dredges (benthic macrofauna). Video footage and dive samples were used to inspect the new hard substrate created by monopiles, while calibrated hydrophones assessed the acoustic environment at a range of 10m-3000m from the turbines. Fish sampling occurred using trawl and acoustic surveys. Harbor porpoise calls were observed using acoustic porpoise detectors and harbor seal impacts examined tag-reported swimming patterns around the wind farm. Local seabird distributions were established through bi-monthly ship counts from September 2002-February 2004 and again in April 2007-January 2009. Flying bird flight paths through the wind farm were observed both visually and using a fully automated radar.

- Results: 1) The comparison of benthic communities between the mainly sandy areas around the turbines and the reference areas showed no short-term impacts created by the construction or presence of the monopiles based on the Bray-Curtis index. 2) Field surveys during the first nine months of 2007 found no differences in densities of bivalve recruits (>.2mm and >.5 mm) between the impact and reference areas. 3) In total, 33 species were identified on the monopiles that can be separated into two communities; an upper zone (7-10m) and a deeper zone (10m-bottom). Animals in the upper zone included common mussels, barnacles, common starfish, and several species of worms and crabs. The deeper zone was dominated by tube worms, anemones, and amphipods. The species most commonly occurring in the scour protection layer were sea mats, amphipods, and anemones. 4) At low wind speeds (1.8 and 9.7 m/s), noise from the turbines was only detectable up to a range of 300m underwater. All results were indicative of lower noise level production at lower wind speeds. 5) The biomass of pelagic species within the impact site is highly dynamic; different species dominated in certain months and the composition differed between the sampling periods. Demersal fish catches varied as well, but a significant increase inside the wind farm was demonstrated for sole, whiting, and striped red mullet during the summer. In the summer and winter, a significant decrease was found for lesser weaver. 6) Harbor porpoise detection demonstrated strong seasonal variation that produced high detections in the winter months and low detections in the summer. The number of porpoises inside and outside of the wind farm significantly increased during turbine operation. The increase in echolocation activity inside the impact area was also significant. 7) Tagged harbor seals avoided the impact areas during construction but extended their distribution towards the impact area afterwards. 8) The comparison of bird surveys pre- and post-construction are not suggestive of large effects to birds in the area. Bird fluxes measured through visual and radar detection showed bird fluxes were lower post-construction.

- Conclusions: 1) The absence of fisheries from the area likely caused a more explicit correlation between sediment type and bivalve recruitment. The newly introduced hard substratum causes increased biodiversity inside the impacted site. 2) The changes to the fish community assemblages occurred in both the impact and reference areas, so the shift is not being attributed to the wind farm presence. The change is more likely a product of temporal variation, lack of fisheries, and temperature differences between the sampled years. 3) EMFs from the cable or noise produced by regular operation did not seem to have a large impact on fish or other more mobile species. 4) There is insufficient data to draw conclusions regarding harbor seals, but no aversion of operational turbines was noted for harbor porpoises. 5) Some bird species avoid the wind farm, while others are attracted. The turbines influence the species-specific flight patterns of local and migratory birds.

Appendix D. Stakeholder and Agency Letters

RHODE ISLAND
SALTWATER
ANGLERS
Association

P.O. Box 1465, Coventry, Rhode Island 02816 401-826-2121 FAX: 401-826-3546 www.RISAA.org

Offshore Wind Farm Recreational Fishing Research Protocol Considerations

Prepared by the Rhode Island Saltwater Anglers Association

January 23, 2019

The Rhode Island Saltwater Anglers Association's (RISAA) Board of Directors would like to thank Bay State Wind, Deepwater Wind/Orsted and Vineyard Wind for attending our November 26, 2018 seminar and answering many questions from our members.

As we have stated to you in the past, we are in favor of responsible development of offshore wind energy resources as long as the environment and marine opportunities, including recreational fishing are protected. We would like to take this opportunity to provide the feedback that you requested on two topics:

1. Input regarding proper sampling before, during, and after construction to give an idea of likely impacts to recreational fishing.
2. Input regarding how the tower foundations or anti-scour pads beneath them can be constructed to improve fish habitat.

Regarding #1 above, we would be pleased to work with you or your scientific consultant to help design the details of a sampling program, but we believe that actual field sampling should be started at least 24 months before any construction. Sampling should include rod and reel surveys of bottom fish and pelagic species during spring, summer, and fall periods as well as bottom fishing in rocky areas during winter months.

This sampling should occur in each construction area for at least one year prior (three or four seasons); during the construction period; and for at least two years post construction. A report should be generated that describes sampling methods, results, and interpretation regarding what effects were observed. A follow-up report should be written to evaluate potential mitigation that could be implemented in subsequent construction areas as development continues. Study methods for pelagic fish such as mahi, tuna, sharks as well as mammals should also occur as part of the study protocol. Methods may include aerial surveys, acoustic tagging and other methods to be determined.

In addition, observational studies should be conducted to observe recreational fishing activities occurring in the construction area on a similar schedule. This information should be included in the report mentioned above. An additional aspect of research should include surveying individuals who fish in this area by phone, email, and in-person interviews to determine how their activities in the study area are changing before, during, and after construction. RISAA can help with coordination between these individuals and the researchers.

Regarding #2 above, we believe that the four-legged structures with cross supports used at the Block Island Wind Farm provide better habitat than mono-pile structures and we would prefer seeing that technology used to provide this additional habitat. If mono-pile structures are used we believe that additional structure can be beneficial as habitat and also beneficial to the structures as anti-scour pads. When anti-scour pads are designed the habitat value should be considered.

The National Oceanic and Atmospheric Association (NOAA) has many references to artificial reefs and what makes them productive. They indicate that hard structure rising above the floor of the ocean provides surfaces for encrusting organisms and actual relief provides locations for fish to gain shelter. They recommend hard surfaces like stone, concrete or metal and actual three dimensional spaces like reef balls, concrete pipe sections, caves, etc. Based on this we believe that large rock placed at the base of the tower structures with gaps and voids will provide the best enhanced fish habitat.

It is our goal to have the offshore wind farm industry and the Bureau of Ocean Energy Management (BOEM) develop and implement an offshore wind farm recreational fishing research plan/protocol for each offshore wind farm project. As the largest recreational fishing association in the Northeast, RISAA is willing to act as a catalyst to help industry develop and roll out such a protocol throughout the northeast.

We welcome further discussion at any time.

Please contact
Capt. David Monti 401-480-3444
Capt. Richard Hittinger 401-265-7602
or call our office at 401-826-2121

Commercial Fisheries Center of Rhode Island

P.O. Box 5161, Wakefield, RI 02880
Tel: (401) 874-4568 Web: www.cfcri.org
Email: fredmattera@cfcri.org shayerooney@cfcri.org

Grover Fugate / Director
RI Coastal Resources Management Center
Oliver Stedman Government Center
4808 Tower Hill Road, Suite 3
Wakefield, RI 02879-1900

February 19, 2019

RE: Vineyard Wind – CRMC File No. 2018-04-055

Dear Mr. Fugate,

Vineyard Wind has been engaged with University of Massachusetts Dartmouth's School of Marine Science and Technology and local stakeholders to develop a pre- and post- construction monitoring program to measure the project's potential impacts on fisheries resources (Monitoring Plan). Vineyard Wind and SMAST designed these fisheries studies for those from the fishing community that have a history of fishing in the VW leased site, as well as regulators and academia. They would have a lead role in identifying the concerns to be addressed through these studies. Several workshops were conducted throughout the region to garner fishermen's input, one notably here in November of 2018 at the Commercial Fisheries Center of RI on East Farm. At the workshop SMAST described the initial bottom trawl survey conducted in October 2018 utilizing an open codend/video sampling technique. SMAST concluded that the video system was not effective due to the composition of the bottom affecting the visibility making this sampling method ineffective. SMAST did conduct 21 closed codend tows which were used to assess abundance, spatial distribution, size and length-weight relationship for targeted species in the area.

However, we would like to identify several flaws in the trawl survey design. In referencing the trawling activity from the VTR and VMS monitoring that RI DEM (Julia Livermore/2018 Addendum) provides of the vessels from RI, Mass., CT. and NY. (Tables during 2011-2016) in and adjacent to the VW leased site it is clear that 90% or more of the trawling is conducted by RI fishing vessels. RI fishermen have a long and productive history (decades) of fishing on these grounds. The majority

Proudly Representing:
Ocean State Fishermen's Association, RI Commercial Fisherman's Association, RI Lobstermen 's Association, RI Shellfishermen 's Association, Eastern New England Scallop Association, RI Monkfishermen 's Association, Point Judith Fishermen Memorial Foundation, Commercial Fisheries Research Foundation, RI Party & Charter Boat Association, Pt. Judith Scholarship Foundation

of RI fishermen use graduated 4 panel (box net) design nets (identical to the NEAMAP net design) with a headrope height of 12' to 15' as opposed to the 2-seam net design from the New Bedford trawler (SMAST collaborated trawler) with a maximum of 6' to 8' headrope height. Much less effective when measuring species, abundance and distribution. Both NEFSC and NEAMAP use identical nets and gear (NEFSC rockhopper sweep/NEAMAP cookie sweep) with a long time series making this the preferred net and design by SMAST for this trawl survey. Therefore, the relative efficiency of the two surveys allows a meaningful comparison. In essence, the RI fishermen unanimously agreed, at the RI workshop that any future trawl survey should be conducted by RI trawlers using the NEFSC/NEAMAP net and gear design to present a realistic assessment. This is major concern and needs to be addressed in the immediate future.

Additional List of fishing industry concerns and measures:

1. Trawling fishing activity in and surrounding the VW leased site has been RI centric for 15 years or more, justifying a collaboration with RI vessels.
2. Grave concern with the location of the Control Area, too close to the Survey Area and Construction Area affording a skewed result.
3. BOEM and Ocean SAMP require a minimum of 2 years Baseline Study prior to construction, this will not be accomplished.
4. Ventless Trap Survey should be conducted using lobstermen that have a proven history of fishing these grounds, they are familiar with the bottom and the migration pattern of lobsters and Jonah crab. RI lobstermen have conducted ventless trap surveys for the last 5-6 years on these grounds and have a time series of experience and knowledge. A compelling consideration to continue with the existing lobstermen.
5. Important to develop a model for active fishermen and fisheries representatives to provide significant input in the design of fisheries studies.
6. Paramount to establish a fishermen/research working group to guide studies underway. This working group should be continued to benefit long term regional studies.

Thank you for the opportunity to provide our relative and troubling comments to positively impact and initiate the first viable Monitoring Plan. Let's strive to get this right now and set the pathway for beneficial monitoring in the future.

Respectfully,

Frederick J Mattera
Executive Director/CFCRI

cc. Eric Stephens VW
Stephen Cadrin SMAST
Kevin Stokesbury SMAST
Lanny Dellinger FAB/CRMC

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Northeast Fisheries Science Center
166 Water Street
Woods Hole, MA 02543-1026

Cristiana Banks
Vineyard Wind
700 Pleasant St., Suite 510
New Bedford, MA 02740

February 28, 2019

Dear Ms. Banks,

Thanks for sharing your fisheries monitoring plan, entitled, "Submission re Fisheries Studies Final," with the Northeast Fisheries Science Center (NEFSC). On the evening of February 25th, 2019 NOAA received the draft with your request to review and provide comments back to Vineyard Wind within four days so that Vineyard Wind could commence studies. Unfortunately, NOAA Fisheries is not able to provide official comments on the Vineyard Wind Monitoring Plan as the submitted plan lacks sufficient detail and critical information to evaluate its efficacy. Clearly defined objectives, underlying research, methods, and justification would be essential given the scale and magnitude of the proposed Vineyard Wind project. The proposed efforts, as described, may fit the definition of site characterization studies but not a monitoring plan. Despite these shortcomings and unreasonable review period, I can offer the following initial comments based on brief consultation with NEFSC scientific staff, and as described below.

It is not clear from the proposed submittal what research questions and hypotheses are being tested and why. The proposed plan lacks necessary supporting data, research, and analysis, including an evaluation of sampling strategies; and recommendations to justify the conclusions presented in the proposed monitoring plan. The plan should also describe how the proposed studies, methodologies, and statistical analyses addresses the input received during Vineyard Wind engagement with regulatory and fishing communities.

Specifically, there is little description of the survey and sampling designs that would be utilized for the various monitoring methods nor any description of the statistical methods that would be used to test these hypotheses. For example, What was the question posed to the power analysis that was conducted? Similarly, it is not evident that any stratification has been planned in either the trawl or drop-camera surveys though there is certainly very good benthic habitat survey data available to build a survey design. There are also likely specific habitats of concern that were identified by industry and resource agencies that should be treated in the survey design.

The proposed plan provides no basis for the selection of sample sizes and thus this can not be evaluated. Initial evaluation by NEFSC staff indicate that the proposed sample size is likely too small to be able to be used in any reasonable manner. However, without presentation/evaluation of any data and clearly articulated hypotheses to test against; it is impossible for NOAA to review the effectiveness of the proposed sampling and justify the activities proposed.

Although the submitter references making the data collected by the proposed studies available to future regional studies there is no description of these regional surveys or plans to collaborate with others to design them; and how adaptive monitoring strategies would be executed. We also recognize that no other entities or management authorities have provided Vineyard Wind or SMAST with a synoptic regional monitoring plan to integrate site-specific monitoring programs. We recommend that should you pursue the current plan that you recognize that your efforts would be expected to be modified or expanded in the future as regional standards/monitoring programs are developed either through pending regulatory processes or other discussions by resource management agencies, developers, or other collaborative arrangements.

In terms of timing constraints for obtaining immediate input into the design and construction of your proposed trawl survey net specifications, NOAA cannot offer any specific recommendations at this time. We would note that there is much more information required than just constructing an identical net to the inshore regional trawl survey performed by the F/V Darana R through NEAMAP. Should a trawl survey be recommended to meet research objectives; a deliberative process that taps the expertise from industry and trawl survey design leads in the region should be pursued in the scoping, design, evaluation, and construction of a new trawl survey; including establishing the necessary performance standards. In order to evaluate survey design, it goes well beyond understanding the net itself and these details are not described in the proposed monitoring plan, e.g., vessel attributes, door configuration, and ability to monitor gear performance. We do not advise simply constructing a net using Darana R NEAMAP survey specifications and beginning to sample without first addressing these and other questions.

Further, NOAA shared scoping level comments with VWW regarding the project's impacts to federal fisheries surveys, including impacts to the federal bottom trawl survey. The project's layout will result in hazardous safety conditions for federal vessels seeking to access sampling areas and would impact execution of current sampling methodologies and procedures. Specifically, the project would have direct impacts on the federal multi-species bottom trawl survey conducted on FSV Henry Bigelow, the Surfclam/Ocean Quahog clam dredge survey conducted on chartered commercial fishing platforms, the integrated benthic/sea scallop habitat survey, and the shelf-wide Ecosystem Monitoring Survey. Any untowable areas (and their vicinities) along the submarine cable routes would create additional exclusions to current sampling protocols.

While the area of the Vineyard Wind project area may not on its own result in a substantive loss of sampling area for these federal surveys, taken in conjunction with the impending development of other foreseeable future lease developments, the removal of large areas of habitat available to these surveys could have deleterious impacts on federal survey operations and could have consequent impacts on a multitude of fisheries stock assessments. Since we will lose survey access for this and other surveys, NOAA had requested Vineyard Wind to address these effects and potential impacts (loss of precision and accuracy) of the many stock assessments that are underpinned with this data. NOAA Fisheries has not received any response to these comments and the DEIS claims the project will have a minor beneficial impact on regional scientific surveys. Based on preliminary analysis, the area covered by turbine footings would result in either a loss of sampling area and/or require the development of new alternative survey methodologies and protocols.

NEFSC has not conducted the required analyses to determine the full range of impacts of these sampling area exclusions on the myriad of stocks dependent on these data streams. Some examples of likely impacts include the following: removal of sampling area from assessments may reduce the precision on stock assessment indices of abundance and the accuracy of assessment indices due to survey availability effects; impacts due to required changes in random survey design protocols; and efforts to design and conduct new survey methodologies and protocols that could effectively sample in wind energy areas would also impact precision due to the time to build robust/usable time series. Any environmental impacts due to the construction and operation of Vineyard Wind could result in impacts to survey gear performance, gear efficiency, and availability e.g., increased sedimentation and water clarity impacts on video or drop-camera survey operations; and lighting effects on fish behavior. In addition, any displacement of vessels due to changes in transit corridors or displacement of recreational and commercial fishing effort could further exacerbate the availability of sampling area for NOAA survey operations.

The design of new monitoring surveys such as the Vineyard Wind proposal should consider how proposed new surveys address the impacts to these core regional surveys and proposed alternative sampling program plans should consider the design, experimental evaluation, and calibration with existing survey methods. The process to develop new surveys and methods should be subject to a deliberative peer-review process consistent with federal fisheries stock assessment processes.

Please free to contact me at Andrew.lipsky@noaa.gov or 401-829-8286 if you would like to discuss these comments further.

Sincerely,

Andy Lipsky
Planning Officer
Lead for Fisheries and Offshore Wind Energy
NOAA Fisheries
Northeast Fisheries Science Center

Appendix E. Initial proposal for drop camera survey

Project Summary:

We will use the University of Massachusetts Dartmouth School for Marine Science and Technology (SMAST) drop camera survey to examine the benthic macroinvertebrate community and substrate habitat in the area proposed for offshore windfarm development by Vineyard Wind. The data set collected under this proposal will provide a baseline for future environmental assessment of windfarm development and can be linked to the existing SMAST drop camera data set. The objectives of this survey are to provide 1.) distribution and abundance estimates of dominant benthic megafauna, 2.) classification of substrate type across the survey domain, and 3.) comparison of benthic communities and substrate types between the development area, control area, and broader regions of the U.S. continental shelf. Further, this survey will 4.) classify substrate within aliquots sampled by the Massachusetts Lobsterman Association-SMAST trap survey of the area, if that project is funded

Methodology: We will survey within and near areas leased to Vineyard Wind for offshore wind energy development (Figure 1). Survey stations will be placed through a systematic grid design and a drop camera pyramid will be deployed four times at each station. The pyramid will be equipped with two downward-looking cameras providing quadrat samples of the seafloor for all stations. Additionally, a third camera providing a 0.6 m^2 view of the seafloor or a view parallel to the seafloor, may also be deployed. At each station, images will be collected for laboratory review. Within each quadrat epibenthic invertebrates, 50 total taxa that can include squid egg clusters, will be counted or noted as present, and the substrate will be identified. For animals present, the percent of a quadrat they were present in will be calculated. After the images have been processed a quality assurance check will be performed on each image for accuracy.

Rationale: The primary experiment for assessing anthropogenic impacts on natural habitats is the Before-After-Control-Impact (BACI) design. This design assumes that the control and impact areas have similar environments and communities and that these communities will change in a similar fashion over time except for the disturbance caused by human action. To conduct this experiment requires preliminary information allowing the selection of appropriate control areas and determination the number of samples required to statistically test the hypothesis of impact. In 2012 and 2013, SMAST conducted drop camera surveys of proposed offshore windfarm leasing areas, including the areas now leased to Vineyard Wind. The results from this survey indicated that the benthic invertebrate community and habitat within the windfarm lease areas were not like other areas of the U.S. continental shelf and that a control area needed to be near the development site. Further, analysis of the variability of the dominant benthic invertebrates in the previous study suggests at least 60 sites, but ideally close to 200, are needed in the control and development area to provide an adequate sample size to test the hypothesis of impact. The current Vineyard Wind benthic monitoring plan contains 10 video transects for which the presence of epibenthic invertebrates will be noted within the development area. This is unlikely to provide enough baseline data to support a comprehensive BACI study of benthic animals or to assess if the area is providing a “reef” or “sanctuary” effect. Here we propose a drop camera survey on a 1.5 km grid that provides high-resolution benthic images for about 130 stations in the development area and 120 stations in a control area. The survey will also provide additional stations on a 5.6 km grid in other Vineyard Wind lease areas not scheduled for immediate development to provide preliminary data. This survey and subsequent analysis will drastically increase the benthic community data within the development area and begin to establish the composition of this community in relation to the control area. This work will leverage SMAST's broader drop camera dataset, which has contributed in numerous ways to understanding the ecology of benthic invertebrate communities and the characterization of benthic habitat, helping to link results to broader regions of the U.S. continental shelf as more windfarm development occurs. The past work SMAST has conducted with the local fishing community, including drop camera surveys since 1999, will aid in the recognition of project results.

Project Narrative:

Rational: The fundamental goal of the SMAST drop camera survey is to provide fishery resource managers, marine scientists and fishing communities with an independent assessment of scallop resources and associated habitats. The survey techniques were developed collaboratively with scallop fishermen and apply quadrat sampling methods based on diving studies (Stokesbury and Himmelman 1993,1995). Initial surveys in the early 2000s focused on estimating the density of sea scallops within closed portions of the U.S Georges Bank fishery, but the survey expanded to cover most of the scallop resource in U.S. and Canadian waters (≈100,000 km^2) (Malloy et al 2015, Bethoney et al 2017). Information from the survey has been incorporated into the scallop stock assessment through the Stock Assessment Workshop process and reliably provided to the New England Fisheries Management Council to aid in annual scallop harvest allocation (NEFSC 2010, 2018). Since 2014, collaboration with Clearwater Seafoods Inc. and other Canadian scallop companies, has resulted in data from the drop camera survey used in Canadian scallop harvest and allocation decisions. In addition, data from the drop camera survey has contributed in numerous ways to understanding the ecology of non-scallop species (Marino et al. 2009, MacDonald et al. 2010, Bethoney et al 2017, Rosellon-Druker and Stokesbury 2019) and the characterization of benthic habitat (Stokesbury and Harris 2006, Harris and Stokesbury 2010, NEFMC 2011, Harris et al. 2012). This work includes contributions to update several ecosystem-based management activities such as the New England Fisheries Management Council Swept Area Seabed Impact model (NEFMC 2011) and define habitat characteristics and spatial distribution of benthic marine invertebrates in potential wind energy areas off the coasts of Maryland and southern New England in conjunction with the Bureau of Ocean Energy Management. Based on this history, the SMAST drop camera survey can aid Vineyard Wind in environmental impact monitoring related to benthic animals and habit (Guida et al 2017).

To comply with state and federal guidelines, as well as best practices in environmental impact monitoring, sampling of windfarm development areas must be conducted before, during and after construction in impact and control areas. The current Vineyard Wind benthic habitat monitoring plan has strengths but is lacking in benthic community assessment in the development area. The plan contains 10 video transects for which the presence of epibenthic invertebrates will be noted and generally characterized within the development area (Vineyard Wind 2018). This level of baseline data and analysis if not enough for a comprehensive BACI (Underwood 1991, 1992) or to address criticisms of claims windfarms provide a "reef" or "sanctuary" effect (RODA 2019). This work will provide a level of data benthic epibenthic invertebrates, and potentially some fish, that if repeated could investigate these questions (Stokesbury and Harris 2006). Further, results can be used to supplement grab and multibeam sounder work conducted through the habitat monitoring plan. For example, SMAST and The Nature Conservancy collaborated to create a data set that combined images and grab sample to describe comprehensively describe substrate on the U.S. continental shelf (Figure 1). Lastly, this survey will be conducted with the same systematic design as other SMAST drop camera surveys, linking it to the broader area and allowing results to be used to assess population level impacts as more windfarm development occurs on the U.S. continental shelf (Figure 2).

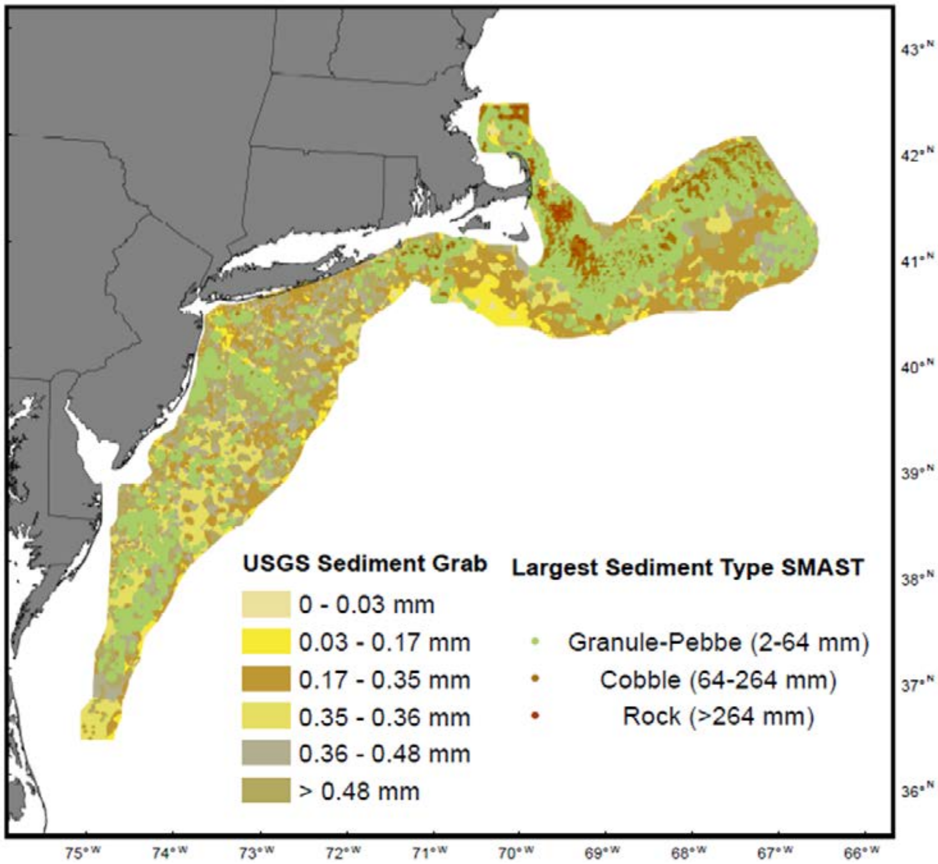

Figure 1. Map from dataset of SMAST drop camera hard-bottom integrated with soft-bottom grab data

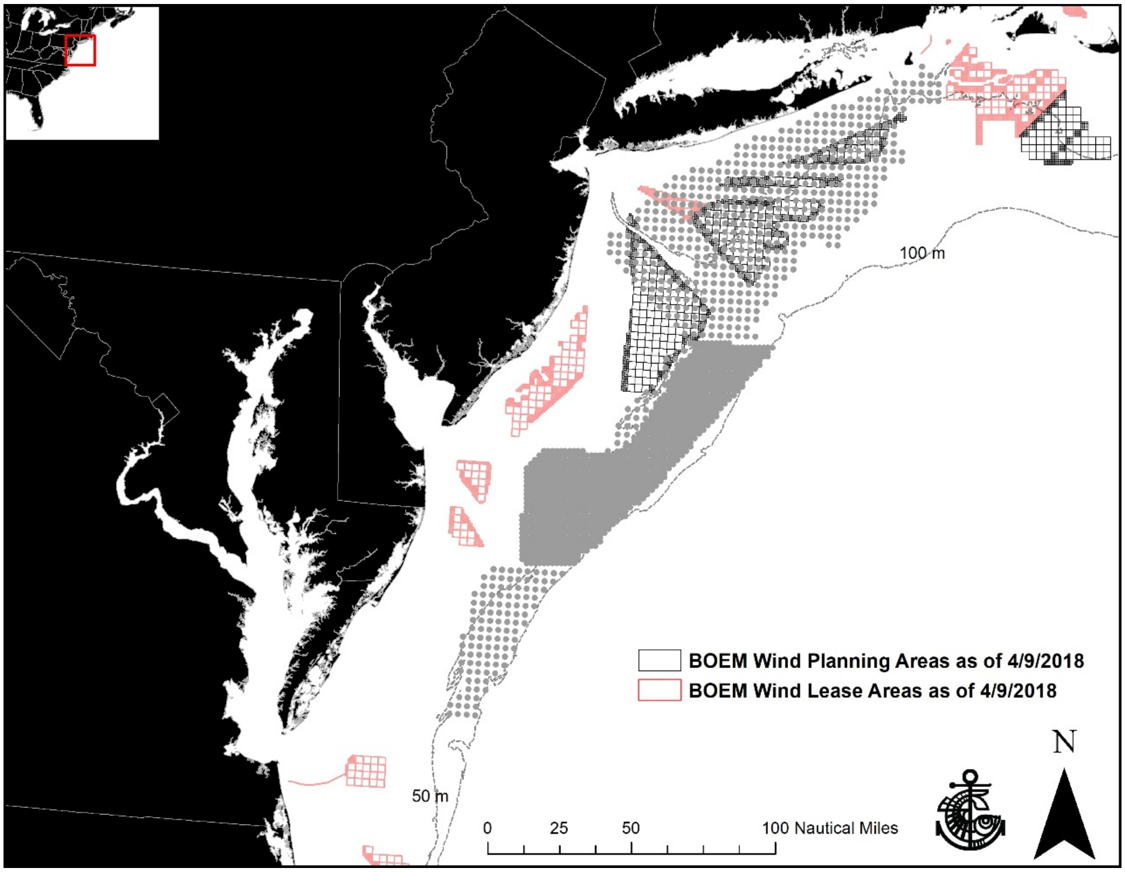

Figure 2. Windfarm planning and lease areas with planned 2019 drop camera stations (grey dots = 5.6 km grid, grey fill = 2.8 km grid)

Objectives and Methods: The primary goal of this project is to provide a baseline for future environmental assessment of windfarm development impact in the Vineyard Wind development area (Figure 3). The objectives of this survey are to provide 1.) distribution and abundance estimates of dominant benthic megafauna, 2.) classification of substrate type across the survey domain, and 3.) comparison of benthic communities and substrate types between the development area, control area, and broader regions of the U.S. continental shelf. Further, this survey will 4.) classify substrate within aliquots sampled by the Massachusetts Lobsterman Association-SMAST trap survey of the area, if that project is funded.

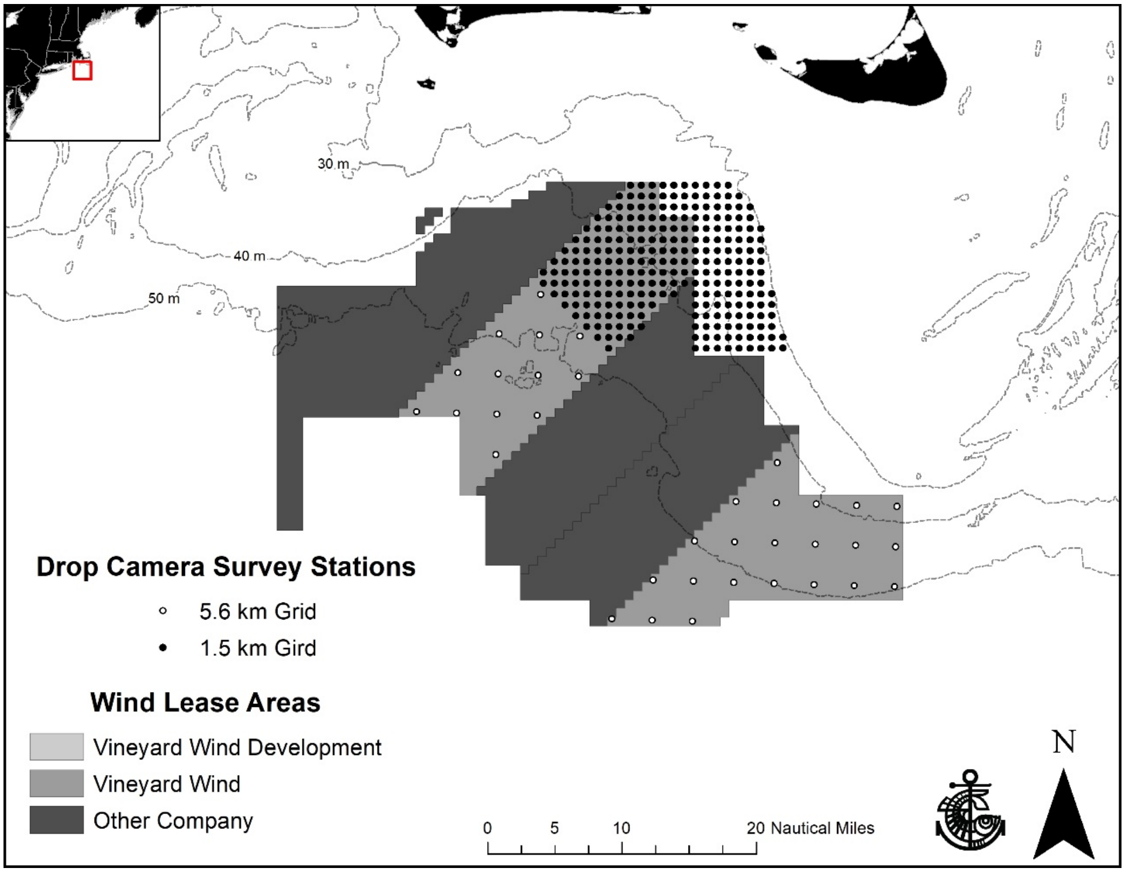

Figure 3. Drop camera survey station grids and wind lease areas.

A centric stratified, systematic sampling design with four quadrats sampled at each station will be used to survey stations on a 1.5 km grid in the Vineyard Wind development area, a nearby control area not slated to be leased for wind energy development and on a 5.6 km grid in areas leased to Vineyard Wind for future development. This will result in about 130 stations in the development area, 120 stations in a control area, and 35 stations in the leased areas. The control area was defined by an adjacent area with the same latitude boundaries as the development area deeper than 30 m that did not intersect with wind lease areas. This will result in the control area being shallower than the development area but is the best continuous location for a control site near the development area. The control area could be moved further away to achieve similar depths but results from the 2012 and 2013 drop camera surveys of this area indicated that a control area needed to be near the development site. The grid resolution was based off analysis of the variability of the dominant benthic invertebrates observed in the 2012 and 2013 surveys that suggested at least 60 sites, but ideally close to 200, were needed in the control and development area to provide an adequate sample size (Krebs 1989). The stations will be sampled during 1, 5-day research cruise.

During the survey, a sampling pyramid, supporting cameras and lights will be deployed from a commercial fishing vessel (Stokesbury 2002, Stokesbury et al. 2004, Bethoney and Stokesbury

2018). A mobile studio including monitors, computers for image capturing, data entry, and survey navigation (software integrated with the differential global positioning system) will be assembled in the vessel's wheelhouse. The vessel will stop at each pre-determined station and the pyramid will be lowered to the sea floor. Two downward facing cameras mounted on the sampling pyramid will provide 2.3 m^2 and 2.5 m^2 quadrat images of the sea floor for all stations. Additionally, a third camera providing a 0.6 m^2 view of the seafloor or a view parallel to the seafloor, may also be deployed. Quadrat images from all cameras and video footage from the 2.5 m^2 quadrat view of the first quadrat will be saved and then the pyramid will be raised, so the seafloor can no longer be seen. The vessel will drift approximately 50 m and the pyramid will be lowered to the seafloor again to obtain a second quadrat; this will be repeated four times. In the event this sampling pyramid is unavailable, the sampling pyramid used in 2016 and for one survey in 2017, which deploys a Kongsberg digital still camera (1.7 m^2 quadrat image), will be used. Onboard the survey vessel, scallop counts, station location, and depth will be recorded and saved through a specialized field application for entry into a SQL Server Relational Database Management System.

After the survey, the high resolution digital still images will be used as the primary data source (Figure 4). Within each quadrat, macrobenthos will be counted or noted as present, and the substrate will be identified (Stokesbury 2002, Stokesbury et al. 2004, Bethoney and Stokesbury 2018). Fifty taxa of macrobenthos are counted or noted as present or absent. A complete list of these taxa and how they are tracked can be found in Stokesbury and Harris 2006. For animals noted as present, the percent of a quadrat they were present in will be calculated by portioning the quadrat into equal sized cells and noting presence or absence in each cell. In addition, longfin squid *(Doryteuthis (Amerigo) pealeii)* egg clusters, which are not typically enumerated, will be counted (Figure 4). Sediments will be also be visually identified following the Wentworth particle grade scale from images, where the sediment particle size categories are based on a doubling or halving of the fixed reference point of 1 mm; sand = 0.0625 to 2.0 mm, gravel = 2.0 to 256.0 mm and boulders > 256.0 mm (Lincoln et al. 1992). Gravel will be divided into two categories, granule/pebble = 2.0 to 64.0 mm and cobble = 64.0 to 256.0 mm (Lincoln et al. 1992). Shell debris will also be identified. Other images and video will be used to aid in the counting and fill in any data gaps created by stations missing images from a high resolution digital still camera. After the images have been digitized a quality assurance check will be performed on each image for accuracy of counted and identified species.

Figure 4. Example digital still image taken by the SMAST drop camera with a longfin squid *(Doryteuthis (Amerigo) pealeii)* egg cluster can be seen in the top, middle of the image.

Mean densities and standard errors of animals counted will be calculated using equations for a two-stage sampling design where the mean of the total sample is (Cochran 1977):

$$\bar{\bar{x}} = \sum_{i=1}^{n} \left(\frac{\bar{x}_i}{n} \right)$$

where *n* is the number of stations and $\bar{x}_i$ is the mean of the 4 quadrats at station *i*.

The SE of this 2-stage mean is calculated as:

$$S.E.(\bar{x}) = \sqrt{\frac{1}{n}(s^2)}$$

where: $s^2 = \sum^{n} (\bar{x}_i - \bar{\bar{x}})^2 / (n-1)$.

According to Cochran (1977) and Krebs (1989) this simplified version of the 2-stage variance is appropriate when the ratio of sample area to survey area (*n*/*N*) is small. In this case, thousands of square meters (*n*) are sampled compared with millions of square meters (*N*) in the study area. A similar multi-stage approach will be used to calculate mean presence values. Mean abundance values (density or percent present) will be mapped and statically compared between the control and development sites. The analysis will be limited to the 12 most abundant animal groups (Bethoney et al. 2017).

A percent similarity index (Renkonen 1938) or similar metric will be used to measure similarity between benthic community and substrate types between the development area, control area, and broader regions of the U.S. continental shelf. This index compares relative proportions of taxonomic categories present in each area standardized as a percentage of the total categories observed. The approach will use species occurrence to assess the spatial dominance of species categories as opposed to the number of individuals observed as abundance comparisons will do. This will allow for a more comprehensive model of the benthic communities, as rarer species will not be excluded due to the extraordinarily high abundance of the few dominant species.

However, this comparison will include only species that are sessile or exhibit locally mobile behavior (Asci et al. 2018).

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Appendix F. Initial proposal for ventless trap and larval survey

Project Summary:

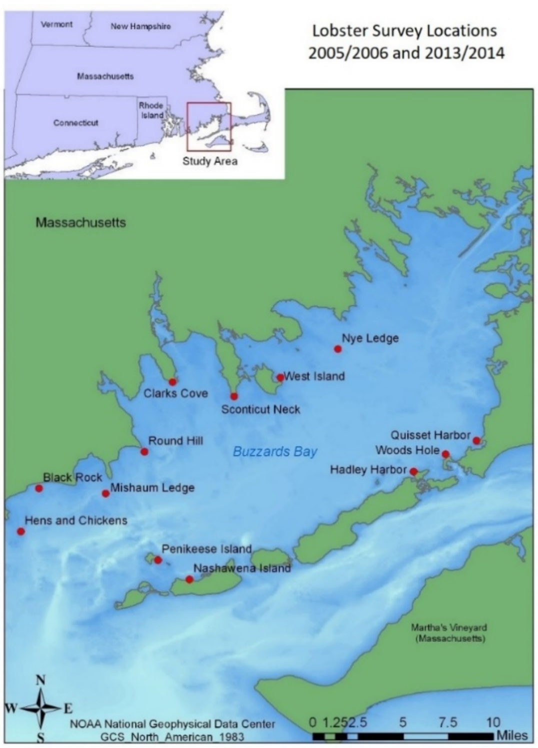
The University of Massachusetts Dartmouth School for Marine Science and Technology (SMAST), in conjunction with the Massachusetts Lobstermen's Association (MLA), seek to establish a ventless lobster trap survey with a tagging component to assess the American lobster resource in the Vineyard Wind development area and adjacent control sites. Concurrently a black sea bass study will be conducted at the recommendation of the Massachusetts Division of Marine Fisheries (MADMF) to gather much need data on relative abundance, fecundity, feeding habits, as well as age and size structure. We will also determine relative abundance and distribution of larval lobster and fish using a towed neuston net. Substrate and habitat classification will be determined from data collected during a separate SMAST drop camera optical survey. Results from this study will provide a baseline for federal and state mandatory monitoring plans.

Methodology: SMAST will survey the northern development area and an adjacent control area; both areas are of similar size and depth. Each lease cell in the development area is divided into 16 sub-areas called aliquots; this design was transposed to the control area. Within each cell a randomly selected aliquot will serve as the center point for the study area; a total of 30 stations will be selected and split equally between the development and control areas. At each station a string of lobster pots will be sampled twice per month. All captured lobsters will be carefully recorded and appropriately sized samples will be tagged. Results will produce relative and absolute abundance, size and sex distribution, reproductive state, recruitment, and severity of epizootic shell disease. Bycatch from the traps will be recorded and assessed; particularly species of commercial interest such as Jonah crab. Adjacent to each sting, a single black sea bass trap will be collected and samples will be analyzed for age, diet, and population structure. The plankton sampling component of this study will utilize a towed neuston net to sample the top 0.5 meters of the water column. At each station three 7-minute tows will be conducted to assess pre-settlement abundance and distribution.

Rationale: The ideal method to assess the impact or change on an environment is through a Before-After-Control-Impact (BACI) study. The design of this experiment assumes that the development area and control area have similar environments and over time would change at the same levels. This study will provide a baseline on the American lobster and black sea bass as well as temporal abundance and distribution of lobster larvae in the neustonic layer of the water column. Results from this study will be able to be compared to follow up assessments after construction. Ventless trap surveys are widely accepted methods for relatively assessing populations (Courchene and Stokesbury, 2011). This methodology is utilized by New York and aside from Connecticut, every coastal state in New England as well (ASMFC, 2015). Ventless trap surveys have previously been used with success in the pre-construction monitoring in the Rhode Island/Massachusetts wind energy area (RI/MA WEA), located on Cox's Ledge lease area (Collie and King, 2016). The current Vineyard Wind monitoring plan calls for research on the adult lobster population as well as plankton sampling; this study will satisfy both components. As an additional component the black sea bass monitoring will be conducted at the request of the MADMF as part of their recommendation for environmental assessment in wind energy development areas (MA DMF, 2018).

Project Narrative

Rationale: The Vineyard Wind lease area begins roughly 15 nm south of Martha's Vineyard. The MA WEA has several major lease areas awarded to various companies for offshore wind development. As part of extensive pre- and post-construction research initiatives, School for Marine Science and Technology (SMAST) was asked to conduct ventless lobster trap, black sea bass pot, and plankton surveys to assess the impact of wind farm development on these species. Ventless lobster traps have been used by both MADMF and RIDEM to assess the status of the American lobster in southern New England (ASFMC, 2015) and implemented in several graduate student projects at the SMAST (Figure 1a) (Courchene and Stokesbury, 2011; Cassidy, 2018). This provided a strong baseline of the American lobster and Jonah crab resources within the RI/MA WEA around Cox's Ledge (Collie and King, 2016) and in the United Kingdom (Roach et al., 2018). Lobster stocks in the Gulf of Maine have increased to record highs (ASMFC, 2019), while Southern New England has declined to extreme low levels; effectively collapsing (Le Bris et al. 2018). The southern New England lobster resource and associated fishery have moved offshore areas where the stock has re-distributed (Figure 1b and 2) (Glenn et al., 2011; Cassidy, 2018). This is caused by increasing water temperatures inshore and the thermosensitivity of lobsters (Wahle et al., 2015).



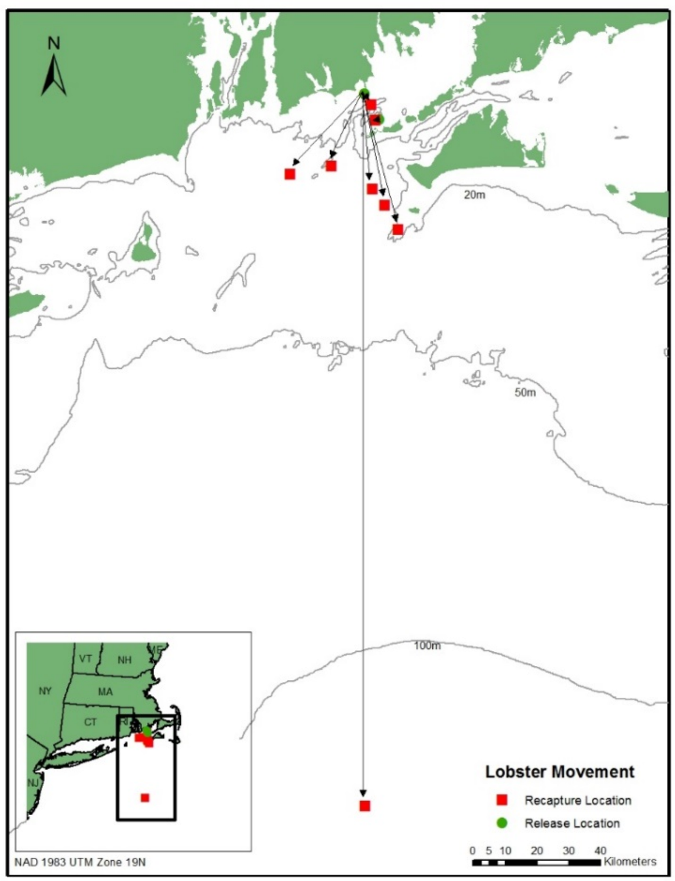


Figure 1a. (Left) Previous sampling locations of SMAST ventless trap survey in both 2005/2006 and 2013/2014. Figure 1b. (Right) Lobster recaptures reported by commercial fishermen from a tagging study in 2013/2014.

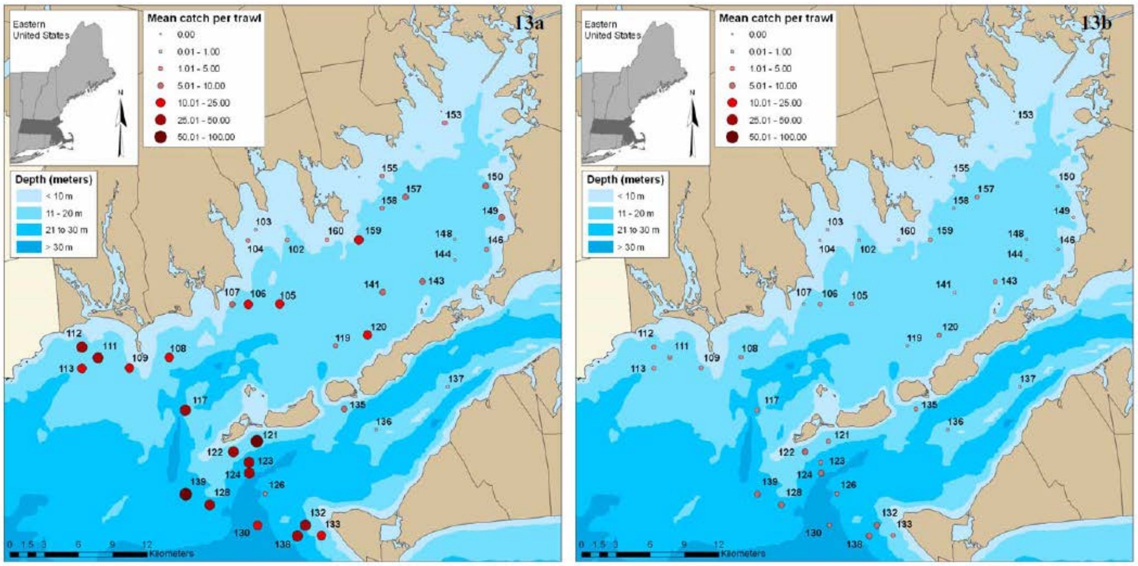


Figure 2. Catch distribution of DMF trawl survey for 2007 for sublegal and (b) legal sized lobsters, labels represent sampling station IDs (provide by B. Glenn).

<u>Objectives and Methods:</u> The goal of this project will be to provide a baseline for the environmental impact assessment for the Vineyard Wind development area and adjacent control areas (Figure 3). Our primary objectives are to 1) Estimate the size and distribution of lobster and black sea bass populations in the development and control areas, 2) Classify population dynamics of each species including, length, sex, reproductivity success, age, diet, and disease, 3) Estimate the relative abundance and distribution of planktonic species such as larval lobster and fish in the neustonic layer of each area, and 4) Obtain movement patterns and if possible meet the assumptions for a Jolly-Seber population estimate of lobsters through tagging.

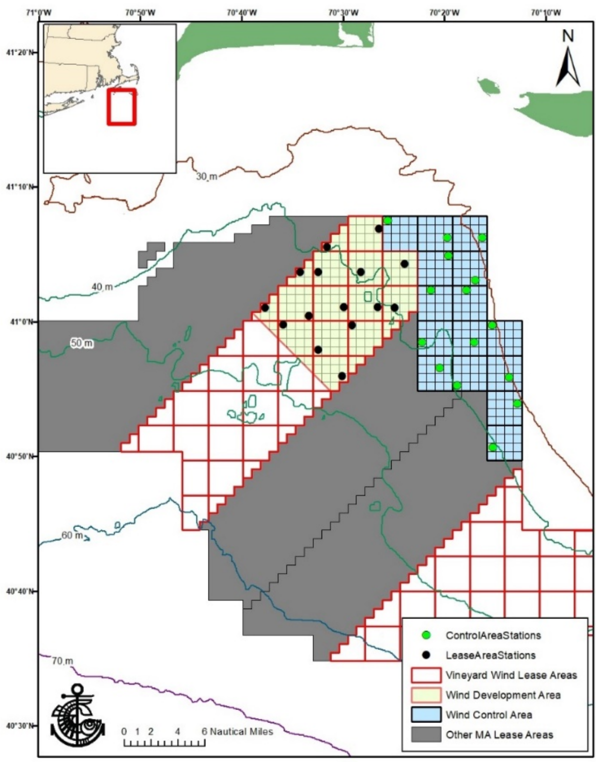


Figure 3. Proposed sampling sites (black and green dots) for 2019 in both the Vineyard Wind development area (yellow) and control area (blue).

Fisheries-dependent trap sampling data historically has been used very selectively to aid in relative abundance indices for American lobster (*Homarus americanus*) because of substantial spatial biases associated with the way these data are collected (ASMFC, 2015). The non-random fashion in which commercial traps are fished introduces a potential source of bias to CPUE estimates, as the fishery actively targets lobster. Instead, trawl survey relative abundance indices have been used for lobster stock assessment purposes because of the randomized sampling design and non-selective nature of trawl gear. However, trawl surveys have potential biases associated with their inability to fish in all productive lobster habitats, such as rock and ledge bottom, as well as in areas where static fishing gear is deployed (traps, gillnets, and bottom longlines) due to gear conflict (ASMFC, 2015).

To minimize the potential biases associated with standard abundance indices we have modified Collie and King's (2016) existing cooperative, random stratified ventless trap survey. This will generate robust estimates of lobster relative abundance and recruitment in the Vineyard Wind development area and control sites. Sampling sites were determined by dividing our strata into "lease blocks" (larger grid cells in Figure 3). Each lease block was then divided into 16 "aliquots." A randomly selected aliquot within each lease block will serve as the site location for the duration of the survey. A map of the study area was overlaid with a latitude/longitude grid in ArcGIS (Figure 3) and shows depth within the area to be relatively uniform. Depth within the lease area ranges from 37 to 49.5m (Vineyard Wind, 2018). This survey design combines the best aspects of both fishery dependent and independent surveys; random stratified sampling design and static fishing gear that can be deployed on any substrate type.

We will sample 30 strings of lobster traps, split equally between the development and control areas. The strings in each area are designed using the standard protocols demonstrated in previous SMAST, DMF, and coastwide ventless trap studies (ASFMC, 2015; Courchene and Stokesbury, 2011). Each string contains 6 pots total, alternating between vented and ventless traps (Figure 4). The dimensions for all traps are standardized (40" x 21" x 16") throughout all survey areas and contain a single kitchen, parlor, and rectangular vent in the parlor of vented traps (size 1 $^{15}/_{16}$" x 5 ¾") will be included. The gear will follow federal rigging regulations; the downlines of each string will utilize new weak link technology to deter whale entanglements. Temperature will be collected using methods described by Cassidy (2018). A Tidbit v2™ Temperature Logger will be placed on the first trap of each string to compare CPUE and bottom water temperature.

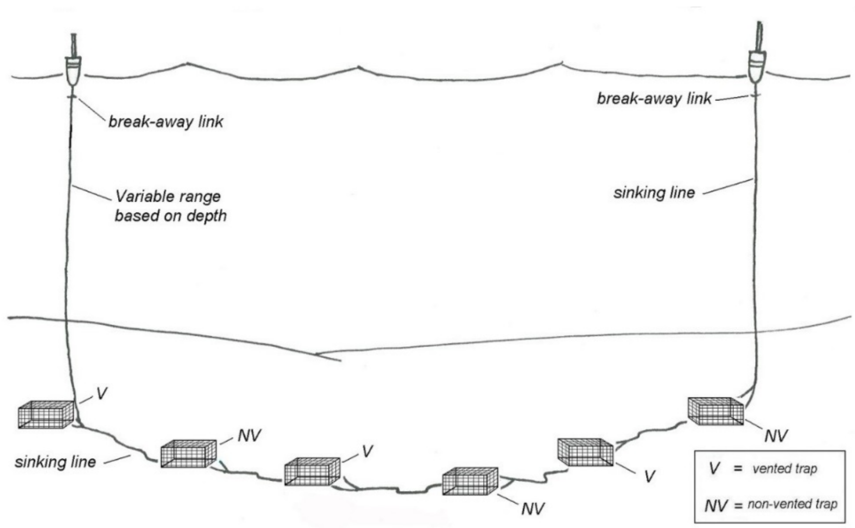


Figure 4. Diagram of the lobster trap array at each sampling location

Trap deployment, maintenance, and hauling are contracted to commercial lobstermen, but sampling will always be conducted by an SMAST researcher on board fishing vessels. To the degree possible, survey gear will be hauled on a three-day soak time, in the attempt to standardize catchability among trips. All trawls will be reset in the same assigned location after each haul. SMAST researchers will accompany fishermen on each sampling trip to record CPUE and biological data using the standard MADMF and RI DEM lobster trap sampling protocol, which enumerates lobsters per trap, number of trap hauls, soak time, trap and bait type, carapace length (to the nearest mm), sex, shell hardness, number of claws or shell damage, presence of shell disease, and egg stages on ovigerous females (ASMFC, 2015). A subset of this data will be collected from the first 5-10 Jonah crabs of each trawl, in addition to the recording of other bycaught species (Collie and King, 2016). Trawl location will be confirmed with the station's original coordinates after each haul via GPS. Depth at mean low water for each trawl location will be recorded from NOAA navigational charts as a coastwide standard to avoid variability from tidal fluctuations. No lobsters or bycaught species will be landed during the survey.

A tagging study will be conducted using the methods described in Courchene and Stokesbury (2011). Lobsters with a carapace length greater than 40mm will be tagged using Floy™ anchor tags inserted with a hypodermic needle. The tag is inserted into the arthral muscle of the animal, so it is retained during molting. Each tag will display an individual identification number and include a phone number for reporting of recaptures by fishermen (Cassidy, 2018). Each tagged lobster will be released at the aliquot of capture, allowing for the spatial assessment of lobster use both within and outside the development area. In order to estimate abundance through tagging study a Jolly-Seber mark-recapture model will be implemented with the following assumptions: 1) Every lobster has the same probability (α_t) of being caught in sample *t,* 2) Every lobster has the same probability of survival from sample *t* to sample *t*+1, 3) Sampling time is negligible, and 4) Marks are not lost between sampling periods (Krebs, 1989). Utilization of the model is as follows:

First calculate the proportion of marked animals, which is called α, to correct for small sample sizes 1 can be added the variables (Krebs*,* 1989):

1) $$\hat{\alpha}_t = \frac{(r_t + 1)}{(c_t + 1)}$$

Next, calculate the size of the marked population prior to sample *t*:

2) $$\hat{P}_t = \frac{(s_t + 1)M_t}{(R_t + 1)} + r_t$$

Finally, a population estimate can then be derived using $\hat{P}_t$ and $\hat{\alpha}_t$:

3) $$\hat{N}_t = \frac{\hat{P}_t}{\hat{\alpha}_t}$$

To calculate the confidence limits and variance transform the estimates as follows:

4) $$\hat{N}_t^* = Ln(\hat{N}_t) + Ln\left[\frac{\sqrt{1 - \left(\left[c_t / \hat{N}_t\right] / 2\right) + \left(1 - \left(c_t / \hat{N}_t\right)\right)}}{2}\right]$$

Variance can be calculated as:

5) $$\delta_{\hat{N}_t^*} = \left(\frac{\hat{P}_t - r_t + s_t + 1}{\hat{P}_t + 1}\right)\left(\frac{1}{\hat{R}_t + 1} - \frac{1}{s_t + 1}\right) + \frac{1}{r_t + 1} - \frac{1}{c_t + 1}$$

Variance can be used to estimate the 95% confidence limits (*L)*, for the transformed values $\hat{N}_t^*$, where the upper limit is:

6) $$L_{\hat{N}_t^*(Lower)} = \hat{N}_t^* - 1.6\sqrt{\delta_{\hat{N}_t^*}}$$

and the lower is:

7) $$L_{\hat{N}_t^*(Upper)} = \hat{N}_t^* + 2.4\sqrt{\delta_{\hat{N}_t^*}}$$

Values can be re-transformed to estimate non-symmetrical confidence limits of the original population estimate:

$$8)\quad \frac{\left(4e^{L_{\hat{N}_t^*(Lower)}}+c_t\right)^2}{16e^{L_{\hat{N}_t^*(Lower)}}} < \hat{N}_t < \frac{\left(4e^{L_{\hat{N}_t^*(Upper)}}+c_t\right)^2}{16e^{L_{\hat{N}_t^*(Upper)}}}$$

This method has been successfully used to estimate lobster abundance in previous tagging studies (Dunnington et al, 2005; Bigelow, 2009).

This study will also aim to assess the black sea bass population. To achieve this, one un-baited fish pot will be set adjacent to each sting of lobster traps and naturally saturate over the soaking period. This will not only be important for collecting general information on this species, but also will allow us to examine relative predation rates on larval and year-of-young lobster (Figure 5). This will be accomplished through stomach content analysis as this species preys on lobster (Wahle, et al, 2013). Sampling of this gear will occur simultaneously with lobster trap hauling. Collections of black sea bass for biological analysis (aging, diet, and fecundity) will be taken at each hauling period; thirty from each area, sixty samples in total.

Photo Credit: Nate Gorry

Figure 5: A recreationally caught black sea bass with emphasis that it has recently consumed a lobster.

We will assess changes to larval lobster abundances. A towed neuston net will collect samples from the same survey aliquots as the traps. This will occur on the days set aside for baiting and setting gear from May through October. The sampling net will be deployed off the stern of the commercial fishing vessels; the frame is 2.4m x .6m x 6 m in size and the net is made of a 1320 micrometer mesh. At each location three tows at 4 knots of approximately 7 minutes each will be conducted. The contents from each tow will be washed into tubs, sorted, and stored in a mixture of 10% formalin: 90% seawater, as described by Cassidy (2018). Once back in the lab, samples will be transferred into 70% ethanol for preservation and lobster larvae will be staged according to Herrick (1911).

All results from the three major components of this study will be summarized in a final report and presented to stakeholders and Vineyard Wind LLC. This study will provide a strong baseline of data for the pre-construction phase of the wind farm development and control area and be utilized in the longer term Before-After-Control-Impact assessment. This research will also serve as a platform for a master's in science research project at the University of Massachusetts Dartmouth School for Marine Science and Technology.

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Appendix G. Initial proposal for trawl survey

Project Summary

The University of Massachusetts Dartmouth School for Marine Science and Technology (SMAST) will plan, coordinate and conduct a trawl survey to assess the fish community in the Vineyard Wind Development Area (VWDA) and an adjacent control area. The survey will be adapted from the NEAMAP protocols to provide a consistent framework with existing surveys in the region and facilitate easier sharing and integration between state and federal agencies. The survey will encompass the approximately 370 km^2 Vineyard Wind Development Area and an adjacent control area of similar size and depths, using a systematic random sampling method. A minimum of 20 tows will be conducted in the development area, and another 20 tows in the control area. For each tow, aggregate species weight, as well as individual lengths and weights will be collected for all commercial fish species. This survey will provide the baseline data on catch rates, population and community structure for a future environmental assessment using the Before/After Control Impact (BACI) framework.

Project Narrative

Objectives

The primary goal of this project is to establish a survey methodology and provide baseline data to for future assessments of the possible effect of wind farm development on fish communities in the Vineyard Wind lease area. Additionally, analysis of the data will yield recommendations toward future survey effort. This project will develop a baseline of species and size composition before construct begins and provide: 1) abundance estimates for all commercially important species from for both the lease area and a control region; and 2) a comparison of the fish community between the two areas. Establishing a control area will allow comparisons of BACI analysis after wind turbines are built. More specifically, this survey will yield estimates of fish abundance, spatial distribution, size structure and length-weight relationship within the Vineyard Wind lease area compared to an adjacent control region of similar depth and seabed characteristics. This will allow an evaluation of the after-construction fish abundance and community structure by comparing them to the same control area.

Methodology

The methodology for the survey will be adapted from the Atlantic States Marine Fisheries Commission's (ASMFC) Northeast Area Monitoring and Assessment Program (NEAMAP) nearshore trawl survey. Initiated in 2006 NEAMAP conducts annual spring and fall trawl surveys from Cape Hatteras to Cape Cod. The NEAMAP protocol has gone through extensive peer review, currently operates near the lease site and uses a commercial fishing vessel (Bonzek et al. 2008). Adapting these existing methods will improve the consistency between survey platforms which should facilitate easier sharing and integration of the data with state and federal agencies.

Survey Design. An initial survey was conducted by SMAST in the fall of 2018. This survey provided an initial description of abundance, spatial distribution, size structure, and length-weight relationships for fish community in that area (Stokesbury and Lowery, 2018). An attempt was made to use the open-codend video-based technology; however, poor visibility due to soft benthic substrates stirred up by the trawl system (e.g. the door and sweep) proved this optical method infeasible. Twenty-one survey tows with the traditional closed-codend method were completed during that trip (Figure 1). Based on the catch data, a power analysis was conducted to inform future survey effort. The results indicated that 20 tows within the lease site and a similar number in the control region would allow for a 95% chance of detecting a 25% change in the population of the most abundant species (i.e. scup, butterfish, whiting and summer flounder).

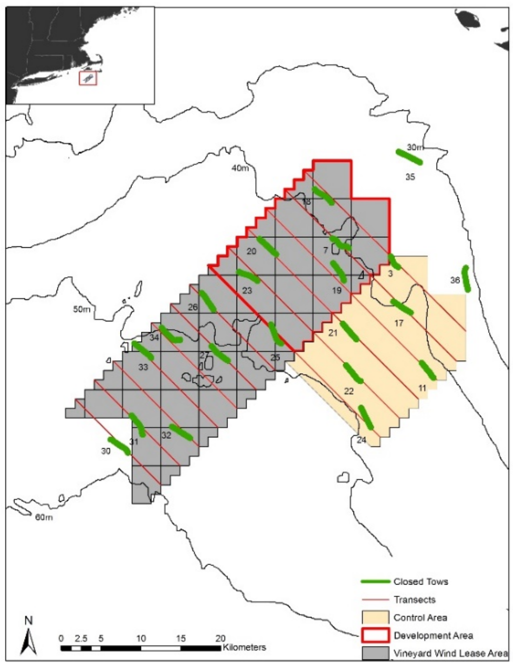

Figure 7. Tow paths from the fall 2018 survey in the Vineyard Wind lease area. The grey polygon with a red outline is the current wind development area. The grey polygon without the red outline is a future development area. The yellow polygon is the control areas.

During this survey we will conduct a minimum of 40 tows; 20 in the 370 km^2 development area, 20 in the 306 km^2 control area (Figure 2). This will give a sampling density of 1 station per 18.5 km^2 (5.4 sq. nautical miles) in the development area. Currently the NEAMAP nearshore survey samples at a density of one station per ~100 km^2 (30 sq. nautical miles). A systematic random sampling design will be used in which each area is subdivided into 20 sub-areas. This will ensure adequate spatial coverage throughout survey regions. The starting location within each area will be randomly selected. Tow duration will be 20 minutes. Tow speed will target at 3.0 knots. For each tow the following environmental and operational data will be collected:

- Start and End Time
- Start and End GPS Location
- Start and End Water Depth
- Tow Speed
- Tow Direction
- Surface and Bottom Water Temperature
- Wind Speed and Direction
- Wave Height
- Air Temperature

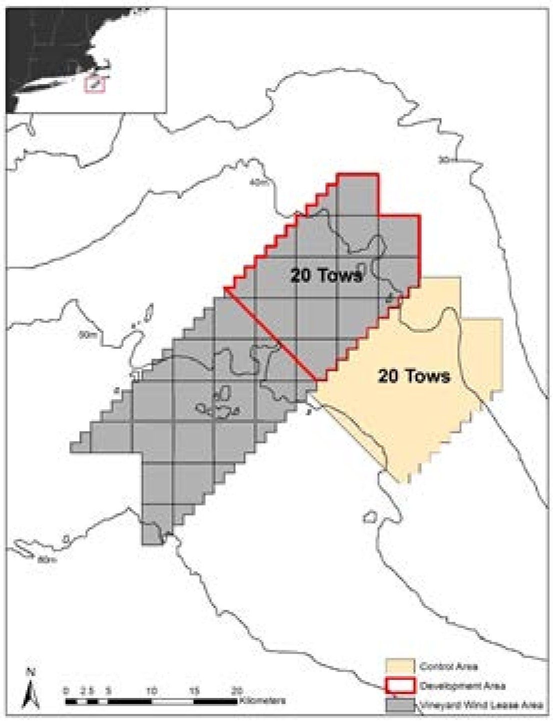

Figure 2. Proposed tow areas for the spring 2019 survey in the Vineyard Wind Development Area (grey with red outline), adjacent control area (yellow), and southern undeveloped area (grey).

***Trawl Design*.** The survey trawl will be a 400 x 12cm, three-bridle four-seam bottom trawl identical to that used in the NEAMAP surveys. The net will include a 12 cm codend with a 2.54 cm (1 inch) knotless liner. This trawl was designed by the Mid-Atlantic and New England Fisheries Management Council's Trawl Advisory Panel. The net design has been accepted by both the scientific community and commercial fishing industry. The net will be paired with a 3" cookie sweep and a set of Thyboron Type IV 66" doors. Prior to the survey the net will be inspected to ensure the construction is within the acceptable tolerance range based on the net certification criteria highlighted in the NEAMAP protocol. Before and after the survey, the mesh size of codend and liner will be measured based on the ICES mesh measurement protocol (Fonteyne, 2005). A commercial fishing vessel (to be determined) will be contracted to conduct the survey. Prior to beginning the survey "test" tows will be conducted to ensure adequate gear performance.

Trawl monitoring. A Simrad PX trawl monitoring system will be used to measure and monitor trawl geometry in real time. Door spread, wing spread, headline height, and bottom contact will be measured for every tow. These data will be used to validate trawl tows against established permissible deviations from targeted geometry. Tows with geometry outside of allowed deviations may be considered invalid. Initially, acceptable trawl parameters will be adopted from the NEAMAP protocol. These values are ±5% of the optimal trawl parameters for wingspread and headline height (as defined by the Trawl Survey Advisory Panel). Additionally, the trawl monitoring system will also log depth and bottom water temperature.

Catch Sampling**.** The catch from each tow will be sorted by species. Aggregated weight from each species will be weighted on a motion-compensated Marel scale. Individual fish length (to the nearest cm) and weights (to the nearest gram) will be collected. Effort will be made to process all animals, however during large catches sub-sampling will be used for some abundant species. Three sub-sampling strategies may be employed: straight subsampling by weight, mixed subsampling by weight or discard by count. When catch diversity is relatively low (5-10 species), straight sub-sampling will be used. In this method the catch will be sorted by species. An aggregated species weight will be measured then a sub-sample (50-150 individuals) will be selected for individual length and weight measurements. The ratio of the sub-sample weight to the total species weight is used to extrapolate the length-frequency estimates.

When catch diversity is high (10+ species) a mixed-subsampling strategy will be used. With this strategy the catch of some large animals/species may be "pre-sorted" to isolate these species and sub-sample these individual species separately. Subsequently, the unsorted catch which usually contain smaller species will be placed into baskets and an aggregated tow weight will be measured. A sub-sample will be sorted, and the relative proportions will be used to extrapolate the total species weight from the unsorted catch. Individual lengths and weights of species will then be collected.

Lastly, the discard by count method will be used when a large catch of large bodied fish is caught, primarily dogfish and skates in this region. For this method a sub-sample of this species (50-100 individuals) will be collected to calculate a mean weight. The remaining individuals will be counted and discarded. The aggregated weight for the species is the total number multiplied by the average weight.

During individual tows multiple sub-sampling strategies maybe employed. The result from each tow will be a measurement of aggregated weight, length-frequency curves and length-weight curves for each species.

***Analysis*.** This data obtained from this survey will serve as a pre-construction baseline for future environmental assessments of impact using the BACI framework. To assess the species abundance before construction in the both treatment areas average catch per unit effort will be compared for each species. Similarly, estimates of abundance and biomass will be calculated. Swept area estimates (km^2) by the survey net will be derived from the trawl mensuration data and a GPS unit (Equation 1). The density by weight, or individuals, and total abundance and biomass in the study area is calculated using Equations 2, 3, and 4 (Gunderson, 1993; Cadrin et al., 2016). The efficiency of the survey net has not been investigated and is assumed to be 100% within the path of the trawl doors so the estimates represent the minimum biomass and abundance within the study area (i.e., the net has 100% herding and capture efficiency).

Equation 1:

$$Area\ swept\ (km^2) = doorspread\ (km) * tow\ speed\ \left(\frac{km}{hr}\right) * tow\ duration\ (hr)$$

Equation 2:

$$Density\ \left(\frac{individuals\ or\ kg}{km^2}\right) = \frac{catch\ (individuals\ or\ kg)}{area\ swept\ (km^2)}$$

Equation 3:

$$Biomass\ (kg) = \ density\ \left(\frac{kg}{km^2}\right) * size\ of\ survey\ area\ (km^2)$$

Equation 4:

$$Abundance\ (individuals) = \ Density\ \left(\frac{individuals}{km^2}\right) * size\ of\ survey\ area\ (km^2)$$

The length and individual weight data will be used to compare differences in the population structure between the two survey areas and serve as a baseline. Kernel density estimates (KDE's) will initially be used to analyze differences in the population structure of each species between the development and control areas (Sanvicente-Anorve et al. 2003; Langlois et al. 2012). This analysis compares the shape and position of the length frequency curve between the two treatment areas. Additionally, the data will be used to assess the community structure between the two treatment areas. Several ordination methods are commonly used in ecological research for this purpose (Anderson and Willis, 2003). These analyses will be useful to inform the adequacy of the selected control site. Finally, the catch data will be used to update the power analysis to inform future survey effort.

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