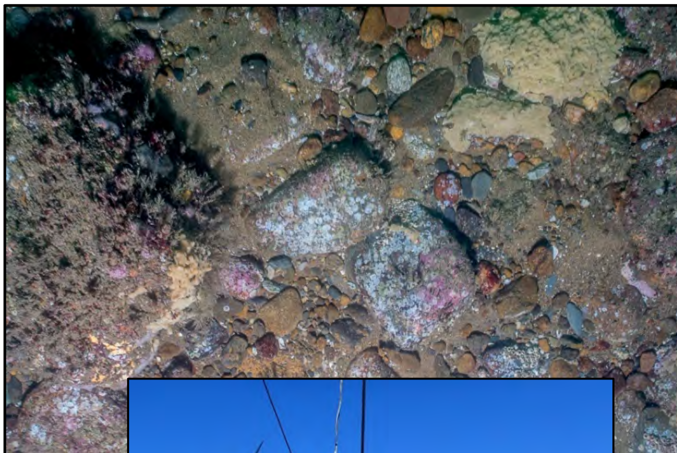
South Fork Wind
Fisheries Research and Monitoring Plan

September 2020



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LIST OF ACRONYMS

ACCOL	Anderson Cabot Center for Ocean Life
ASMFC	Atlantic States Marine Fisheries Commission
BACI	Before-After-Control-Impact
BAG	Before-After-Gradient
BIWF	Block Island Wind Farm
BOEM	Bureau of Ocean Energy Management
CMECS	Coastal and Marine Ecological Classification Standard
COP	Construction and Operation Plan
CPUE	Catch per unit effort
DSLR	Digital single-lens reflex
EFH	Essential Fish Habitat
EFP	Exempted Fishing Permit
ESA	Endangered Species Act
FGDC	Federal Geographic Data Committee
GPS	Global Positioning System
HMS	Highly migratory species
INSPIRE	INSPIRE Environmental, LLC
LOA	Letter of Acknowledgement
LPIL	Lowest possible identification level
MADMF	Massachusetts Division of Marine Fisheries
MARACOOS	Mid-Atlantic Regional Association Coastal Ocean Observing System
MMPA	Marine Mammal Protection Act
NERACOOS	Northeastern Regional Association of Coastal Ocean Observing Systems
NEAMAP	Northeast Area Monitoring and Assessment Program
NEFSC	Northeast Fisheries Science Center
NOAA	National Oceanic and Atmospheric Administration
NYSERDA	The New York State Energy Research and Development Authority
OCS	Outer Continental Shelf
PV	Plan View
RICRM	Rhode Island Coastal Resources Management
RIDEM	Rhode Island Department of Environmental Management
SFEC	South Fork Export Cable

SFW	South Fork Wind
SFWF	South Fork Wind Farm
SMAST	School for Marine Science & Technology
SNECVTS	Southern New England Cooperative Ventless Trap Survey
SPI	Sediment Profile Imaging
WEA	Wind Energy Areas

1.0 Introduction

This Fisheries Research and Monitoring Plan (the plan) has been developed for the South Fork Wind Farm (SFWF or Project), which is proposed to be located in Bureau of Ocean Energy Management (BOEM) Lease Area OCS A-0517, which is within the Rhode Island – Massachusetts Wind Energy Area (RI-MA WEA) (Figure 1). [1] SFWF includes up to 15 wind turbine generators (WTGs or turbines) with a nameplate capacity of 6 to 12 MW per turbine, submarine cables between the WTGs (Inter-array Cables), and an offshore substation (OSS), all of which will be located approximately 19 miles (30.6 kilometers [km], 16.6 nautical miles [nm]) southeast of Block Island, Rhode Island, and 35 miles (56.3 km, 30.4 nm) east of Montauk Point, New York.

1.1 Monitoring Plan Development

This monitoring plan has been developed in accordance with recommendations made by BOEM's "Guidelines for Providing Information on Fisheries for Renewable Energy Development on the Atlantic Outer Continental Shelf" (BOEM, 2013; BOEM, 2019) and by state agencies (RICRMC, 2018; NYSERDA, 2017; MADMF, 2018). In addition, as described in detail below and in Appendix A attached hereto, this plan was refined and expanded through an iterative process that considered feedback from agencies and stakeholder groups.

By way of background, in 2017, the South Fork Wind (SFW) team began meeting with regional fishing organizations, working groups, and individual fisherman to gather information on the fisheries in the SFWF area. Through the permitting and development process, the SFW team also consulted with several states (e.g., NY, CT, RI, and MA) and federal fisheries resource management agencies (BOEM, NOAA) about the fisheries in the SFWF area. With the information collected during these interactions, the SFW team prepared an initial version of the fisheries monitoring plan that contained a gillnet survey because gillnet gear was identified as the primary gear used by commercial fisheries in and around the proposed SFWF area, and because sampling in SFWF with an otter trawl was not a viable monitoring option. *See* Section 2.0 for details on the gillnet survey.[2]

The initial version of the plan was widely circulated for comment in November 2018 to state and federal agencies, regional working groups, advisory boards, research institutions, fishing groups, and other stakeholders. These entities and groups provided the SFW team with numerous comments that it took under consideration as it developed the next draft of the plan. *See* Appendix A.[3] While set forth in more detail in Appendix A, some of the key comments during this time period were: need for a power analysis to determine level of sampling; seasonal sampling intensity needed to increase; more specific information was needed on the sampling gear to be

[1] South Fork Wind, LLC, now a wholly-owned indirect subsidiary of North East Offshore, LLC, a joint venture between Ørsted and Eversource , submitted the major federal permit application, The South Fork Wind Farm Construction and Operations Plan (COP), to BOEM in June, 2018 and submitted a revised COP to BOEM in May, 2019.
The full revised COP document can be found online at: https://www.boem.gov/South-Fork/

[2] References to sections contained herein are to show that additions to the plan were made based on comments that the SFW team received.

[3] Please *see* Appendix A, which presents a summary of key comments received in writing and verbally on the various drafts of the plan. In addition, all written comments received are attached as exhibits to Appendix A.

used; and that a gillnet survey alone was not enough to effectively sample the area. *See* Appendix A for more details.

The SWF team then sought additional feedback on the plan during two webinars in March 2019 with state and federal agencies. Comments from those webinars informed the team about additional gear types that could be used for fisheries monitoring. *See* Appendix A. As a result of the feedback from the webinars and previous comments, a second draft of the fisheries monitoring plan was circulated to agencies and stakeholders for review in June 2019. This draft included the addition of a beam trawl survey protocol. *See* Section 3.0 herein. Also, modifications to the gillnet protocol were made based on comments received previously and additional feedback from industry members. *See* Appendix A. These modifications included adjustments to the sampling schedule and soak time of the survey and the decision to use a single mesh size and tie-downs to address questions about potential interactions with protected species. These changes to the sampling gear also mimic the practices of the commercial fishery and will allow comparability with commercial catch data. *See* Section 2.3 herein. More specific details regarding the sampling gear were also added to the plan. *See* Sections 2.1 and 2.2 herein.

Development of the plan continued through the summer of 2019 incorporating more comments and feedback on the second version of the plan. These comments included the necessity of sharing monitoring data with scientists in the region, feedback that additional gear types should be used for monitoring beyond the gillnet and beam trawl, and the location of the Reference Areas. *See* Appendix A. In September 2019, the SFW team attended two meetings of the Rhode Island Coastal Management Council's (RICRMC) Fishermen's Advisory Board (FAB) to discuss the fisheries monitoring plan. The FAB commented on the proximity of proposed Reference Areas to the SFWF development area as well as the Reference Areas being within areas identified for future development. The FAB also reiterated previously received comments on the need to conduct a power analysis to determine the level of sampling for each survey type. *See* Appendix A.

During the fall of 2019, the SFW team undertook extensive efforts to determine different Reference Area locations that were situated away from any potential impacts from development but were still of comparable depth and habitat as the impact area. *See* Section 2.2 herein. In addition, a power analysis was conducted for the beam trawl survey. *See* Appendix B herein. A power analysis was attempted for the gillnet survey. Comparable fishery-independent datasets for the region, however, are lacking for gillnet gear and the little data that were available did not adequately inform the power analysis to determine a proper level of sampling.

Continuing with the solicitation of feedback, SFW had productive in-person meetings in October and November of 2019 with scientists at Rhode Island Department of Environmental Management (RIDEM) and the Massachusetts Division of Marine Fisheries (MADMF) to review the new Reference Areas and the beam trawl power analysis. The comments received during these meetings are in Appendix A, and both agencies responded positively to the power analysis and new Reference Areas. *See* Appendix A. Meetings with individual fishermen also were conducted to gather additional feedback on the adequacy of the Reference Areas. Through these meetings, a consensus emerged that the new Reference Areas had similar bathymetry, benthic habitats, and species assemblages as the SFWF area. *See* Appendix A. Given the lack of data for a gillnet power analysis, discussions led to the decision to use an adaptive sampling approach whereby a power analysis would be performed after the first year of the survey to determine if the level of sampling would need to be adjusted in subsequent years. *See* Section 2.7 herein. These decisions on the Reference Areas and power analysis were provided to the FAB in late 2019 and added to the evolving plan. *See* Appendix A.

In February 2020, the SFW team attended another FAB meeting to discuss the amendments to the second version of the plan made in late 2019. The FAB stated that the two survey designs contained in the plan (gillnet and beam trawl) would not adequately sample the entire species assemblage at the SFWF site and suggested a one day workshop with the SFW team, state and federal agency scientists, area researchers, and industry members to outline a complete monitoring plan and discuss additional sampling gears. The Commercial Fisheries Research Foundation (CFRF) hosted the workshop and facilitated its development. *See* Appendix A. The workshop was conducted in March 2020 with the SFW team, individuals from the RI CRMC, FAB, RIDEM, NOAA, and several local industry members. *See* Appendix A. Species to be monitored and additional gear types were reviewed and discussed for potential addition to the plan. As a result of this meeting, ventless lobster trap, ventless fish pot, and benthic survey protocols were all added to the new version of the plan, which was distributed in May 2020. *See* Sections 4.0, 5,0 and 7.0 herein. Additionally, the SFW team has pledged to provide financial support for two projects being conducted by area researchers that use acoustic telemetry to monitor Atlantic cod and Highly Migratory Species (HMS) in and around SFWF and surrounding wind energy areas (WEAs). *See* Section 6.0 herein.

Following the release of the revised plan in May 2020, the SFW team hosted an inter-agency webinar on May 22nd. Following the webinar, NOAA, MADMF, NYDEC, and RIDEM provided additional feedback on the monitoring plan. The major feedback received included the need for a power analysis for the ventless trap monitoring plan, the need for a data sharing plan, consideration of spatial and temporal overlap between high-resolution geophysical surveys and fisheries monitoring, and the desire to see more details regarding the adaptive sampling strategy that was proposed. In response to these comments, substantial revisions were made to the monitoring plan. Appendix C was added to the plan, which describes the High-Resolution Geophysical survey equipment that may be used at SFWF, and describes how the operational frequency of that equipment compares to the auditory abilities of fish in the region. A data sharing plan was also added to the Plan (*see* Section 8.0), and a power analysis was completed for the ventless trap survey (*see* Appendix D). Finally, the plan was revised to better describe the specifics associated with the adaptive sampling approach (*see* Sections 2.7, 3.7 and 5.7). Further details are also provided in Appendix A.[4]

[4] As stated above, for more detailed information on the timeline and development of this plan, please also refer to Appendix A.

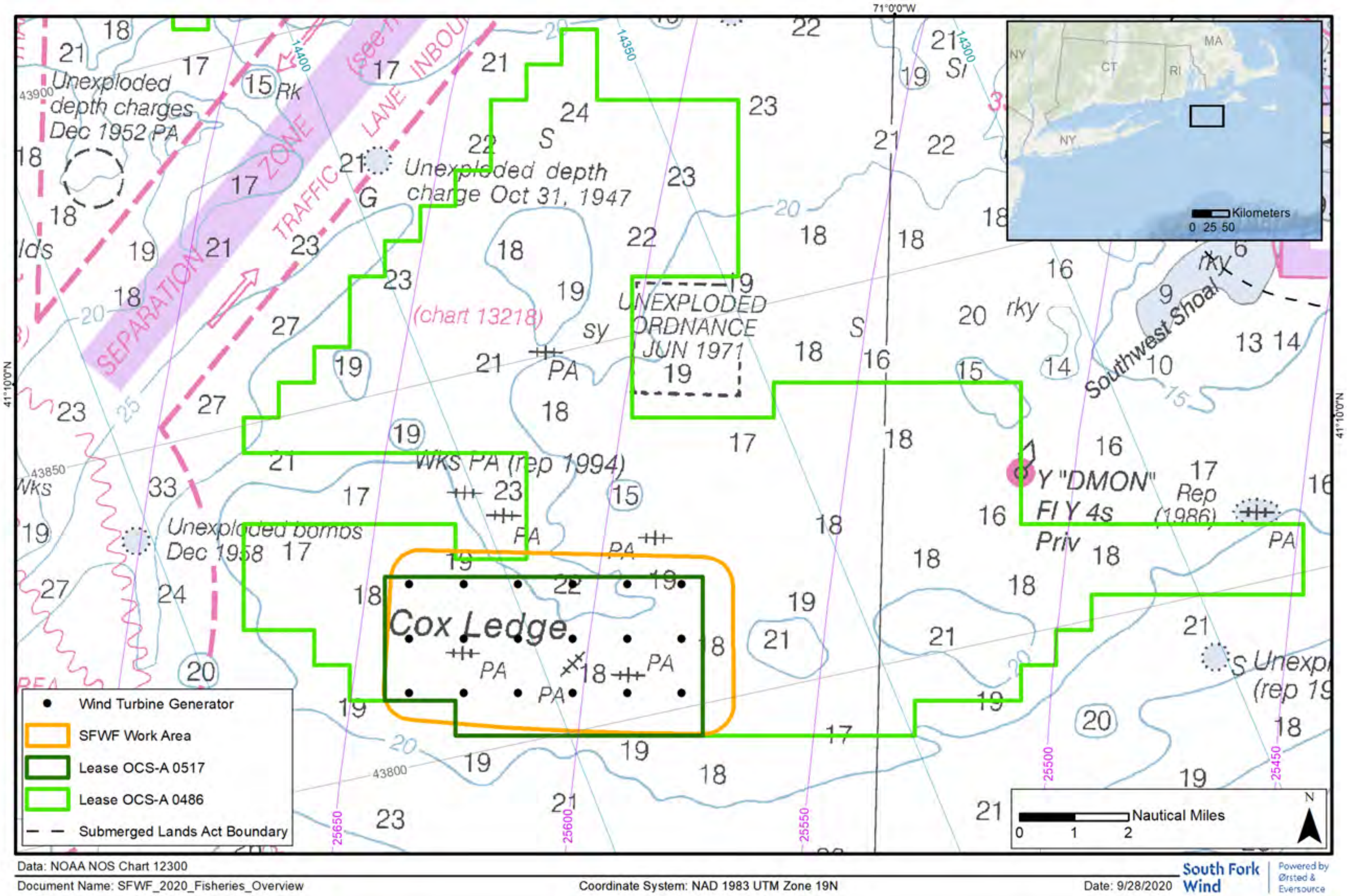

Figure 1. **Location of South Fork Wind Farm**

1.2 Overview of Fisheries Monitoring for South Fork Wind

SFW is committed to conducting sound, credible science. Biological surveys, developed in coordination with the commercial fishing fleet and state agencies, were conducted at the Block Island Wind Farm (BIWF) from 2012 through 2019. The guiding scientific principles implemented beginning with the BIWF and continuing into the future include:

- Producing transparent, unbiased, and clear results from all research;
- Working with commercial and recreational fishermen to identify areas important to them;
- Collecting long-term data sets to determine trends and develop knowledge;
- Promoting the smart growth of the American offshore wind industry;
- Focusing on maintaining access and navigation in, and around, our wind farms for all ocean users;
- Completing scientific research collaboratively with the fishing community;
- Being accessible and available to the fishing industry;
- Utilizing standardized monitoring protocols when possible and building on and supporting existing fisheries research;
- Sharing data with all stakeholder groups; and
- Maintaining data confidentiality for sensitive fisheries dependent monitoring data

The SFWF site is situated atop Cox Ledge, an area with complex bathymetry including extensive areas of boulders and mobile gear "hangs", making it difficult to safely operate large mobile gear (e.g., bottom trawl) in this area. Therefore, the SFWF site is not sampled routinely by the Northeast Fisheries Science Center (NEFSC) bottom trawl survey. Feedback from commercial fishermen, and an analysis of vessel Monitoring System (VMS) data indicate there is little commercial trawl effort in the area. Details of the SFWF fisheries data assessment and early stakeholder feedback can be found in the SFWF COP Appendix Y - *Commercial and Recreational Fisheries Technical Report* (Jacobs, 2018).[5]

The BOEM fishery guidelines recommend that trawl surveys be executed using a stratified random design. However, because of the complex bathymetry throughout the area, it is unlikely that a trawl survey can be safely conducted within the SFWF site using a scientific design with random site selection. Therefore, SFW has evaluated alternative survey designs and monitoring tools that can be used to collect pre-construction data for a wide range of taxa in the SFWF site. With this consideration in mind, the monitoring plan began with an emphasis on using gillnets as a monitoring tool. Over time, the plan evolved to incorporate additional survey techniques that could be executed safely within the SFWF area including a beam trawl, fish pots, ventless traps, and optical approaches to benthic monitoring. Through extensive outreach efforts with the fishing community, feedback from state and federal agencies (outlined in Section 1.1), and exploration of existing datasets (Jacobs, 2018), the SFW team has developed survey designs using multiple sampling gears to acquire pre-construction data on the abundance, biomass, demographics (e.g., length, fish condition, shell disease status), and species composition that occur in and around the SFWF site. In particular, the surveys have been designed to utilize sampling gear that can be fished safely and effectively, and with limited impact, on the complex, rocky habitat within the SFWF site (Thomsen et al., 2010; Malek, 2015).

[5] Appendix Y can be found online at: https://www.boem.gov/Appendix-Y/

Different gear types select for different fish and macro-invertebrate species, therefore, using multiple gear types to sample distinct species assemblages is needed for assessing potential impacts from SFWF (Walsh and Guida, 2017). Consistent survey methods and approaches will allow for data comparisons across studies, collaboration among developers and institutions, and an ability to address questions at appropriate spatial and temporal scales. Several gear types will be used to monitor a large portion of the species assemblage present in and around SFWF. However, it is acknowledged that the monitoring tools proposed herein may not sample for all of the species present within SFWF, particularly some of the smaller pelagic fauna (e.g., Atlantic herring, squid, and butterfish) that are too small to be retained in the gillnet gear, and are unlikely to be captured in substantial quantities by the beam trawls or fish pots. Some sampling will occur seasonally, while other sampling efforts will occur throughout the year (Figure 2). The proposed survey designs in this plan are not exhaustive but will form a basis for fisheries monitoring in the SFWF site. In particular, it is noted that additional fisheries monitoring will be performed along the route of the South Fork Export Cable (SFEC). Those studies are currently being planned in collaboration with local academic researchers and Subject Matter Experts. However, the details and methodologies associated with that monitoring effort are not included in this Plan.

For the gillnet survey, beam trawl survey, ventless trap survey and the fish pot survey, the overarching objective is to determine whether the construction and operation of the wind farm leads to changes in the relative abundance of fish and invertebrate species in the Project Area. The potential impacts associated with the construction and operation of an offshore wind farm have been described in various papers (e.g., Petersen and Malm, 2009; Gill et al., 2012), and it is recognized that several impacts may occur simultaneously (Bergstrom et al., (2013). Therefore, we will evaluate the relative abundance and distribution of fish and invertebrate resources around a wind farm after construction, as compared to abundance and distribution in Reference Areas, and in the Project Area prior to construction (Bergstrom et al., 2013). Our monitoring will be executed with an emphasis on detecting changes in relative abundance, rather than attempting to assess the ecological response to a single impact associated with the construction of an offshore wind farm.

Figure 2. Generic survey timeline for SFWF monitoring

These surveys will provide data that can be used to evaluate:

- Commercially and recreationally important species that utilize the area in and around the SFWF site.
- The seasonal timing of the occurrence of these species.
- Whether the taxonomic composition or relative abundance of fish and invertebrate assemblages change between the pre-construction and post-construction time periods.

The survey protocols have been designed to address requirements and guidelines outlined in the Federal Register (30 CFR 585.626), BOEM fishery guidelines, and RICRMC policies (11.10.9 C).

SFW issued a 'Request for Proposals' on May 5th, 2020 to local Universities and research institutions to execute fisheries monitoring elements of the monitoring plan. The proposals were reviewed in late May and early June, and our scientific research partners were selected in late June 2020. Commercial Fisheries Research Foundation (CFRF) was awarded the contract and will be responsible for executing the gillnet, beam trawl, fish pot, and ventless trap surveys. CFRF will partner with the University of Rhode Island (Dr. Jeremy Collie) to carry out the beam trawl and ventless trap surveys. These scientific researchers have worked collaboratively with SFW to make additional amendments and improvements to the methodologies in the fisheries monitoring plan. It was initially envisioned that field work for these components of the pre-construction monitoring would begin by early fall 2020. However, the start dates for the surveys have been delayed by several factors, including logistical difficulties associated with Covid-19 and delays in the receipt of the scientific research permits that are needed to conduct the monitoring. It is anticipated that the beam trawl monitoring will begin in October, 2020, while the other fisheries surveys (gillnets, ventless traps, and fish pots) will not commence until the Spring of 2021.

Similar to the principles and practices executed for the Block Island Wind Farm, SFW is committed to conducting scientific surveys and assessments that are collaborative with the fishing industry. The scientific contractors selected to perform the monitoring have identified eight local fishing vessels from which these monitoring surveys will be conducted.

2.0 Demersal Fisheries Resources Survey - Gillnet

Gillnet selectivity depends mainly on fish size and shape and mesh size, but is also affected by the thickness, material, and color of net twine, hanging of net, and method of fishing (Hamley, 1975). Using specific gear placements and prescribed mesh sizes, gillnets may be designed to target specific species, or subgroupings of species, and life stages. Southern New England waters are host to an active gillnet fishery that primarily targets monkfish and winter skate. The proposed gillnet survey will focus on monitoring these two species, pre- and post-construction of SFWF, using large-mesh gillnet gear that is designed to effectively target these species.

The objective of the pre-construction monitoring survey is to collect data on the distribution, abundance and composition of demersal fish species in the area of potential affect and in the Reference Areas. The objective of post-construction monitoring is to identify any changes in the fish community in the Project Area between pre- and post- construction that did not also occur at the Reference Areas that could be attributed to either construction or operation of the wind turbines.

At least two years of sampling (*see* Section 2.2. for details) will be conducted prior to the commencement of offshore construction. Similarly, a minimum of two years of monitoring will be completed following offshore construction, but the duration of post-construction monitoring will also be informed by ongoing guidance for offshore wind monitoring that is being developed cooperatively through the Responsible Offshore Science Alliance (ROSA).

2.1 Survey Methods

The survey will be conducted from commercial fishing vessels with scientists onboard to process the catch. For-hire vessels will be selected based on criteria such as experience, safety record, knowledge of the area, and cost. The scientific contractor has applied for an Exempted Fishing Permit (EFP) from the National Oceanic and Atmospheric Administration's National Marine Fisheries Service (NOAA Fisheries) in order to use the hired fishing vessels as a scientific platform and conduct scientific sampling that is not subject to the Atlantic Coastal Fisheries Cooperative Management Act, Magnuson-Stevens Fishery Conservation and Management Act, and fishery regulations in 50 CFR parts 648 and 697. All survey activities will be subject to rules and regulations outlined under the Marine Mammal Protection Act (MMPA) and Endangered Species Act (ESA). Marine mammal deterrent devices will be used on all gillnet gear as required under regulation. All gear restrictions, closures, and other regulations set forth by take reduction plans (e.g., Harbor Porpoise Take Reduction Plan, Atlantic Large Whale Reduction Plan, etc.) will be adhered to as with typical scientific fishing operations to reduce the potential for interaction or injury.

The requirements described in the Atlantic Large Whale Take Reduction Plan (NOAA, 2018a) for the Northeast gillnet fishery will be followed. At a minimum, the following measures will be used to avoid interactions between the gillnet survey and marine mammals, but additional modifications to the survey gear can be made at the discretion of NOAA:

- No buoy line will be floating at the surface.
- There will not be wet storage of the gear. All sampling gear will be hauled at least once every 30 days, and all gear will be removed from the water at the end of each sampling season.
- All groundlines will be constructed of sinking line.
- Fishermen contracted to perform the field work will be encouraged to use knot-free buoy lines.
- All buoy line will use weak links that are chosen from the list of NMFS approved gear.
- All gillnet strings will be anchored with a Danforth-style anchor with a minimum holding strength of 22 pounds.
- All buoys will be labeled as research gear, and the scientific permit number will be written on the buoy. All markings on the buoys and buoy lines will be compliant with the regulations, and instructions received from staff at the Protected Resources Division.
- Further modifications to the sampling gear can be made at the discretion of the Greater Atlantic Regional Fisheries Office.

2.2 Proposed Sampling Stations

An asymmetrical Before-After-Control-Impact (BACI) design is proposed with three sampling areas: a Project Area within the SFWF "Work Area" and two Reference Areas. The SFWF "Project Area" is defined as the maximum work area required to install the SFWF (yellow outline in Figure 3 below). This includes the maximum spatial extent where vessels or lift barges may anchor during construction around the wind turbines and foundations. Data will be collected in the Project Area (the blue square in Figure 3) and two Reference Areas with similar habitat characteristics as the Project Area. The Reference Areas will serve as an index of demersal fish abundance in Rhode Island Sound in an area outside of the direct influence of SFWF and other planned offshore wind farm development sites in the region. Concurrent sampling in the Project Area and the two Reference Areas will identify whether changes in the relative abundance and demographics of monkfish, winter skate, and other species observed within the Project Area are consistent with regional trends rather than representing a localized impact in the vicinity of SFWF. Several sources of information were used to determine the initial location of the Reference Areas. Bathymetry data was obtained from the Northwest Marine Ecoregional Assessment and the NOAA online bathymetric data viewer (https://maps.ngdc.noaa.gov/viewers/bathymetry/). Spatial information on fishing activity, including VTR data for the gillnet fishery and VMS data for the monkfish fishery was from the Northeast Ocean Data Portal was utilized, along with personal communication with local fishermen. Beam trawl data from Malek (2015) was also considered, and the SFW team sought feedback on the reference locations from staff at Rhode Island Department of Environmental Management and Massachusetts Division of Marine Fisheries.

Following feedback received in July 2020 from gillnet fishermen that are participating in the SFWF fisheries monitoring, the eastern Reference Area that was initially selected was moved to the south (Figure 3). The participating fishermen explained that moving the eastern Reference Area to the south would improve sampling of monkfish during their fall migration. The fishermen also expressed concerned that the eastern Reference Area that was initially selected would provide operational challenges, because of the large amount of macroalgae that is flushed out of Vineyard Sound every fall. The fishermen were concerned that this macroalgae would consistently foul the gillnets and prevent the gear from sampling in a representative manner.

The study design consists of sampling each of the treatment areas with gillnet strings. The proposed sampling areas were selected in consultation with regional stakeholders to ensure that:

1. There is comparability among all sampling areas with respect to current, habitat and depth conditions;
2. The Reference Areas are outside the area of influence from SFWF and other projects that may be constructed during the survey, but are still utilized by the same/similar fish populations;
3. Areas allow optimal operational execution of the survey (e.g., safe operation of the sampling gear, minimal travel times between sampling locations, habitats are suitable for the sampling gear); and
4. Space conflicts are minimized with other active uses to the extent practicable.

As mentioned above, several factors were taken in account when considering the location of the Reference Areas. One important consideration is that the Reference Areas must be located in an area that will not be developed in the future, which is especially pertinent in this case given that SFWF is adjacent to the larger Revolution Wind lease area. The submarine power cables (inter-array and export cables) will emit electric and magnetic fields (EMF) while the wind farm is operational. These impacts will persist over a relatively long temporal scale while the wind farm is operational, but the EMF decays very quickly with distance from the cable and is anticipated to have a negligible impact on fish species (Snyder et al., 2019). Therefore, EMF from the project will not affect the Reference Areas. Conversely, noise from offshore construction and High-Resolution Geophysical (HRG) surveys are a transient impact that occurs across a relatively large spatial scale. While the hearing capabilities of fish depend upon their physiology (Popper et al., 2014; Appendix C), the current guidelines are applied to all species of fish equally and use 150 dβ re 1 μPa as the behavioral threshold (Stadler and Woodbury, 2009). A paucity of experimental data has precluded the establishment of behavioral thresholds for invertebrates (Stadler and Woodbury, 2009). The sound levels associated with foundation installation will depend on several factors; including but not limited to the diameter of the pile, the type of hammer used, the hammer energy, the temperature of the water, and the noise attenuation techniques that are used. Therefore, the Reference Areas are well outside of the direct influence of the proposed activities, with the possible exception of pile-driving noise, which may have the potential to affect fish behavior at the Reference Areas during a brief time period when the foundations are being installed.

Within each area, fishable gillnet lines will be determined through consultation with the participating fishermen and an examination of geophysical survey data. Five gillnet lines per area will be randomly selected for each sampling event, resulting in 15 gillnet strings conducted per sampling event. The five gillnet strings per area are subsamples and catches will be averaged to estimate the CPUE per area per sampling event, which will be used in analyses. This sample size was chosen to minimize sampling error for the mean within each area, while considering practical constraints, such as the need to reduce the potential for interactions with protected species, and also avoid gear conflicts with active fisheries that occur in the Project Area and the Reference Areas. The location of gillnets may be subject to change due to seasonal location of other fixed fishing gear (e.g., lobster pots). If a survey line is found to have poor conditions for setting gillnets it may be moved based on the captain's professional judgement. Sample sizes and sampling strategies may be subsequently modified following data evaluation from the data collected through 2021, including the results of a mid-study power analysis using observed estimates of variance (Section 2.7), however the overall survey design will remain unchanged.

Gillnet sampling will occur each spring and fall, as the gillnets will be sampled twice per month from April-June and again from October-December, which coincides with the majority of commercial gillnet activity as monkfish and skates migrate through the area in spring and fall. The pre-construction monitoring is expected to begin in April 2021 and will continue through December 2022. Sampling in July-September will not occur in order to minimize interactions with protected species (e.g., large whales, sea turtles) and to reduce the likelihood of gear damage that can occur during the seasonal migration of spiny dogfish and larger shark species through the area. Based on feedback from local fishermen, efforts will be made to maintain spatial separation between the gillnet and ventless trap survey gears. Fishermen have expressed concern that dead fish in the gillnets may attract lobster away from the survey traps. Therefore, efforts will be made to avoid setting the survey gillnets near the survey lobster traps, during the months that those surveys are both occurring (May, June, October, and November).

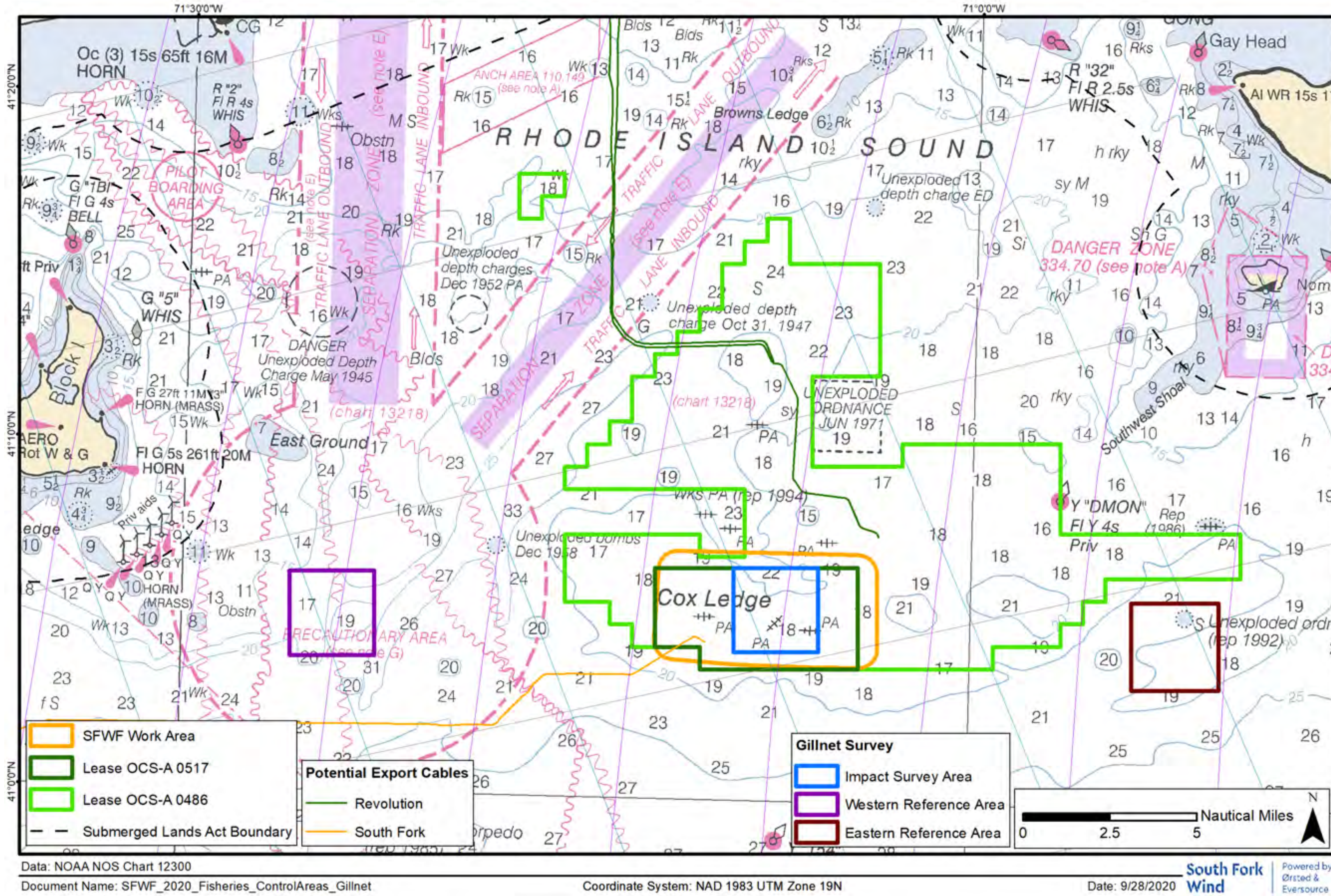

Figure 3. Northeast lease areas including the South Fork Wind Farm with Gillnet Survey Areas.

2.3 Gillnet Methods

A gillnet is a wall of netting that hangs in the water column and is typically made of monofilament or multifilament nylon. Mesh sizes are designed to allow fish to get only their head through the netting, but not their body. The fish's gills then get caught in the mesh as the fish tries to back out of the net. Factors that can influence the catch rate of gillnets for target species include: fish density in the vicinity of gears, the behavior of the target species, the ability of fish to detect and locate the gillnet, and environmental factors such as water temperature, visibility, current direction, and velocity. This survey will use standardized fishing gear and sampling strategies across time and space to standardize catch rates to the extent possible. However, comparison of this gillnet survey data to other pre-construction fishery independent sampling efforts (e.g., nearby federal Northeast Area Monitoring and Assessment Program [NEAMAP]and NEFSC bottom trawl survey stations) may be limited due to the differences in the selectivity and catch rates of the disparate gear types.

The gillnet survey may be conducted using gillnets that are typical of the commercial fishery in Rhode Island and Massachusetts. Each gillnet string will consist of six, 300-ft net panels of 12-inch mesh with a hanging ratio of 1/2 (50%) and using net tie-downs. After much deliberation and discussion with stakeholders, a decision was made to limit the gillnet survey to a single mesh size of 12-inches to target monkfish and skates of commercial sizes. While it was recognized that deploying experimental gillnets with multiple mesh sizes could potentially sample a wider range of species and size classes, this would also necessitate deploying more strings of gillnets, which may have increased the potential for protected species interactions. Further, given the small spatial extent of the Project Area, we were concerned that deploying additional gillnet strings would lead to increases in gear interactions with other user groups in the area. Therefore, the decision was made to utilize a single mesh size of 12-inches, with the primary objective to monitor changes in the relative abundance of monkfish and winter skate in the Project Area and the Reference Areas.

The standard soak time of approximately 48 hours is proposed after input from industry, to maximize catch and standardize catch rates, while also ensuring the gear fishes properly during the soak (i.e., not collapsed from saturation), to minimize depredation of catch, and to improve the logistics of the survey. Soak time will remain consistent throughout the duration of the survey, to the extent practicable. Each sampling event will be managed by a team of qualified scientists including a lead scientist with experience performing fisheries research. The catch will be removed from the gillnets by the boat crew for processing. The lead scientist will be responsible for collection of data and data recording.

Fish collected in each gillnet will be identified, weighed, and enumerated consistent with the sampling approach of NEAMAP. When large catches occur, sub-sampling may be used to process the catch, at the discretion of the lead scientist. The three sub-sampling strategies that may be employed are adapted from the NEAMAP survey protocols and include straight subsampling by weight, mixed subsampling by weight, and discard by count sampling (Bonzek et al., 2008). The type of sub-sampling strategy that is employed will be dependent upon the volume and species diversity of the catch. Scientists will sort and identify fish, and weigh each species by the following protocol:

All organisms will be identified to species. Taxonomic guides include *NOAA's Guide to Some Trawl-Caught Marine Fishes* (Flescher, 1980), *Bigelow and Schroeder's Fishes of the Gulf of Maine* (Collette and Klein-MacPhee, 2002), Kells and Carpenter's (2011) *Field Guide to Coastal Fishes from Maine to Texas*, and *Peterson's Field Guide to the Atlantic Seashore* (Gosner, 1999).

The catch will be sorted by species, and size categories (if appropriate) until the lead scientist verifies that the sorting areas are clear of all specimens. The following information will be collected for each gillnet string that is sampled; abundance and biomass for each species that is captured and length and weight measurements for individual fish belonging to the dominant species and vulnerable (e.g., Atlantic sturgeon) species present in the catch. Notwithstanding sub-sampling procedures, up to 50 individuals of each species/size class will be measured (+/- 0.5 cm) from each gillnet string that is sampled, and the rest counted. A subsample of these individuals will also be weighed (+/- 0.5 g) on a motion compensating marine scale, to evaluate individual fish condition. Individual lengths and weights are recorded on the field data sheet. Fork length is recorded for all fishes with a forked tail. Total length is measured for all other fishes with the exceptions of the following measurements for particular species: rays (disc width), sharks (straight-line fork length), dogfish (stretched total length), crabs (carapace width), lobsters (carapace length), and squids (mantle length). The catch from the gillnet survey will not be retained for sale by the participating vessels, and all animals will be returned to the water as quickly as possible once the sampling is completed.

Stomach content analysis will be performed for commercially important focal species (monkfish, winter skate, gadids, black sea bass) to determine the composition of their prey, and evaluate whether prey composition changes prior to and after construction. Up to 10 animals will be sacrificed for stomach content analyses from each string that is sampled, with no more than 5 individuals of any one species sampled from each string. Each fish sampled for stomach content analysis will be measured (+/- 0.5 cm) and weighed (+/- 0.5 g) individually before the stomach is removed to permit assessment of relative condition. All prey items will be identified to the lowest possible identification level (LPIL), counted, and weighed.

Atlantic cod are known to spawn on or near Cox Ledge (Zemeckis et al., 2014; Cadrin et al., 2020). Sex and reproductive stage will be assessed for the cod sacrificed for stomach sampling according to the protocols used for the 2018 and 2019 SFWF Atlantic Cod Spawning Survey (adapted from Burnett et al. [1989] and O'Brien et al. [1993]). Up to five cod may be sampled per string for sex and maturity and stomach contents. Maturity data from this sampling may be shared with local researchers to better understand the timing and distribution of cod spawning activity in Southern New England.

Should any interactions with protected species (e.g., marine mammals, sea birds, sea turtles) occur, the contracted scientists will follow the sampling protocols described for At-Sea Monitors (ASM) in the Observer On-Deck Reference Guide (Northeast Fisheries Science Center, 2016). Protected species interactions will be reported immediately to NOAA's stranding hotline via telephone (866-755-NOAA) or via the Whale Alert APP, and a follow up detailed written report will be provided to NMFS Greater Atlantic Regional Fisheries Office (incidental.take@noaa.gov) within 24 hours that includes the following information; date, time, area, gear, species, and animal condition and activity. The following protocol will also be followed:

- If a marine mammal take occurs, the entire animal will be retained as time and space allow. However, if there is insufficient space on board the vessel, the minimum sampling requirements described for at-sea monitors will be met.

- If any interactions with Atlantic sturgeon or shortnose sturgeon occur, the contracted scientists will follow the sampling protocols described for the Northeast Fisheries Observer Program (NEFOP) in the Observer On-Deck Reference Guide (Northeast Fisheries Science Center, 2016), which includes collecting a genetic sample and scanning the animal for a PIT tag. Interactions with sturgeon will be reported immediately to NOAA's stranding hotline via telephone (866-755-NOAA) or via the Whale Alert APP, and a follow up detailed written report will be provided to NMFS Greater Atlantic Regional Fisheries Office within 24 hours.

- If an Atlantic sturgeon or shortnose sturgeon carcass is retained, we will contact Fred Wenzel at the Northeast Fisheries Science Center. Any biological data collected during sampling of protected species will be shared as part of the written report that is submitted to the NMFS Greater Atlantic Regional Fisheries Office.
- Sightings of right whales, and observations of dead marine mammals and sea turtles in the water will be reported immediately to NOAA's stranding hotline via telephone (866-755-NOAA) or via the Whale Alert APP and a follow up detailed written report will be provided to NMFS Greater Atlantic Regional Fisheries Office within 48 hours.
- Sea birds will be sampled following the protocols outlined by the Northeast Fisheries Science Center (2016) and if a dead seabird is encountered, any 'dead, fresh' animals will be retained and provided to the US Fish and Wildlife Service for additional sampling.
- Due to the potential for communicable diseases all physical sampling and handling of marine mammals and seabirds will be limited to the extent Ørsted health and safety assessments and plans allow.

2.4 Environmental Data

Hydrographic data will be collected at each gillnet sampling location. A Conductivity Temperature Depth (CTD) sensor will be used to sample a vertical profile of the water column at each gillnet sampling location, following the methods used by the CFRF/WHOI Shelf Research Fleet (Gawarkiewicz and Malek Mercer, 2019). The CTD profile may be collected prior to the string being hauled, or after the string has been hauled, at the discretion of the chief scientist. Bottom water temperature (degrees C) will be recorded at regular intervals (e.g., every 30 seconds) throughout the duration of each gillnet set using a temperature logger mounted on the first panel in each string. Sea state and weather conditions are recorded from visual observations. Air temperature may be downloaded from a local weather station if not available onboard.

2.5 Gillnet Station Data

The following data will be collected during each sampling effort:

- Station number;
- Latitude and longitude;
- Soak start and end time and date;
- Water depth;
- Wind speed;
- Wind direction;
- Wave height;
- Air temperature ; and
- Vertical CTD profile, and continuous observations of bottom temperature while the gear is fishing (*See* Section 2.4).

2.6 Data Entry and Reporting

Data will be transcribed from hard copy datasheets into electronic worksheets. The data sheets will be reviewed for data entry errors prior to importing into a relational database. Quality control checks will be performed on database tables by running standardized, systematic queries to identify anomalous data values and input errors. Species names (common and scientific) will be verified and tabulated for consistency. All data used in analysis will be exported from the relational database.

Annual reports containing catch data will be prepared after the conclusion of each year of sampling and shared with State and Federal resource agencies. One final report will also be produced synthesizing the findings of the pre- and post-construction evaluations.

2.7 Data Analysis

The study will use an asymmetrical BACI experimental design, with statistical evaluation of the differences between reference and Project Areas contrasted in the before and after construction time periods (Underwood, 1994; Smith, 2002). A BACI design will allow for assessment of shifts in fish presence/absence, or relative abundance that correlate with proposed construction and operations at the SFWF site.

Results presented in annual reports will focus on comparing the fish communities in the Project and the Reference Areas to describe spatial and seasonal differences in relative abundance, species composition, and size distribution. For the dominant species in the catch, seasonal catch per unit effort (CPUE) will be compared among the three areas using graphics and descriptive statistics (e.g., mean and variance) and length frequency data by species will be compared among areas using descriptive statistics, graphical techniques (empirical cumulative distribution function [ECDF] plots), and appropriate statistical tests (e.g., the Kolmogorov-Smirnoff test). Species composition will be compared amongst the Project and Reference Areas using a Bray-Curtis Index and multivariate techniques (e.g., nMDS and ANOSIM).

Analysis presented in the final synthesis report will focus on identifying changes in the fish community in the Project Area between pre- and post- construction that did not also occur at the Reference Areas that could be attributed to either construction or operation of the wind turbines (Table 1). With regard to measuring for changes in relative abundance, the research question is to estimate the magnitude of the difference in the temporal changes in relative abundance for winter skate and monkfish observed between the Project and Reference Areas. The null hypothesis is that changes in CPUE (relative abundance) for monkfish and winter skate in both the Reference and Impact Areas will be statistically indistinguishable over time. The alternative hypothesis is that changes in CPUE will not be the same at the Reference and Impact Areas over time (two-tailed). Generalized Linear Models (GLMs) will be used to describe the data and estimate the 90% Confidence Interval (CI) on the BACI contrast. The interaction contrast that will be tested is the difference between the temporal change (i.e., average over the post-construction period minus the average over the pre-operation period) at the windfarm and the average temporal change at the Reference Areas. A statistically significant impact would be indicated by a 90% CI for the estimated interaction contrast that excludes zero. Using a 90% CI allows 95% confidence statements for the lower or upper bound (e.g., if the lower bound of the 90% CI for the mean is greater than 0, this indicates 95% confidence that the mean exceeds 0).

For diet data, the primary question that will be asked is whether the prey composition of monkfish, winter skate, and other focal species changes following the construction of the wind farm. The null hypothesis is that changes in diet between the Impact and Reference Areas are statistically indistinguishable over time. Monthly diet data for focal species will be obtained from stomach contents, and prey composition will be calculated separately for each species as the mean proportional contribution (W_k) of each prey item (Buckel et al. 1999a; Bonzek et al. 2008) by month and area, where:

$$\%W_k = \frac{\sum_{i=1}^{n} M_i q_{ik}}{\sum_{i=1}^{n} M_i} * 100$$

$$q_{ik} = \frac{w_{ik}}{w_i},$$

and where

n is the total number of gillnet strings that collected the fish species of interest,

M_i is the sample size (counts) of that predator species in the gillnet string i,

w_i is the total weight of all prey items in the stomachs of all fish analyzed from gillnet string i, and

w_{ik} is the total weight of prey type k in these stomachs.

Potential seasonal differences in prey composition will be explored for each focal species using multivariate techniques (e.g., nMDS, ANOSIM, and SIMPER). A stomach fullness index (FI) will be calculated for each fish analyzed. The difference between full and empty stomach weights will be determined to obtain the total weight of food (FW). The ingested food weight (FW) is expressed as a percentage of the total fish weight according to a formula defined by Hureau (1969) as cited by Ouakka et al. 2017.

$$FI = FW / \text{fish weight} \times 100$$

More detailed or appropriate analyses may be included as the Project progresses. Data analysis will be executed in accordance with the BOEM fishery guidelines.

Table 1. Summary of planned data analysis for the gillnet survey.

Design Overview	Design details	Metrics of Interest	Research Question	Post-Construction Statistical Methods
1 Impact, 2 Reference areas; 2 years Before Construction and ≥2 years After Operation; April-June and October-December (2x per month); 48-hour soak time.	**Sampling frame** = SFW and Reference areas of similar habitat and size. **Observational unit** = day-area (gillnet strings randomized each sampling event; individual strings are subsamples of day-area estimate) **Response variable** = mean catch per day-area. **Error variance** = temporal	**Catch of key species (monkfish, and winter skate)**	What is the magnitude of the difference in the temporal changes in the observed metric between SFW and reference areas?	Fit the GLM or GAM that best describes the data; estimate the 90% CI on the BACI contrast.
	Observational unit = individual fish **Response variables** = % contribution (by weight) of each species contributing to total diet/stomach contents. **Error variance** = among individual fish	**Diet (prey) composition** for key species (e.g., monkfish, winter skate, gadids, black sea bass)	How does diet composition change over time (B/A), or between areas (C/I)?	Bray-Curtis similarity between individual fish; ANOSIM to identify whether significant differences exist between fish from different seasons, years, or locations. Relationships graphically depicted with nMDS.
	Observational unit = individual fish/invertebrate **Response variable** = length **Error variance** = among individual fish/invertebrates	**Length frequency**	How does size structure change over time (B/A)? How does size structure compare between areas (C/I)?	1. descriptive (range, mean) 2. graphical and statistical comparison (between times and locations) of ECDFs using distributional comparison test (e.g., Kolmogorov-Smirnoff).
	Observational unit = individual fish **Response variable** = condition index **Error variance** = among individual fish	**Fish condition index** (i.e., deviations from log-length vs log-weight relationship) by species	What is the magnitude of change in fish condition over time (B/A), or between areas (C/I)?	Find the best fitting model to the condition values by species, and calculate 90% CI of the relevant contrasts.

Definitions:

BAG = before after gradient

90% CI = 90% confidence interval

ECDF = empirical cumulative distribution function

The SFW project team is not aware of any existing fishery-independent gillnet data sets from the region that could be used to perform a power analysis. Therefore, an adaptive sampling strategy is proposed. Upon completion of sampling in 2021, and again following sampling in 2022, a power analysis will be conducted to evaluate the power of the sampling design. The power analysis will be conducted using an approach similar to what was performed for the ventless trap survey (*see* Appendix D). The variance (e.g., RSE) associated with the relative abundance estimates for winter skates and monkfish will be calculated. Power curves will be used to demonstrate how statistical power varies as a function of effect size and sample size (i.e., number of gillnet samples per area). When analyzing changes in the relative abundance of monkfish and winter skate, we will aim to achieve a statistical power of at least 0.8, which is generally considered to be the standard for scientific monitoring (Cohen, 1992). This ensures that the monitoring will have a probability of at least 80% of detecting an effect that is present. A single two-tailed alpha (0.10) will be evaluated during the power analysis. There is a direct relationship between the magnitude of the effect size and the statistical power of the analysis, with greater power associated with larger effect sizes.

The results of the power analysis will be considered and can be used to modify the monitoring protocols in subsequent years. The decision to modify sampling will be made after evaluating several criteria including the amount of variability in the data, the statistical power associated with the study design, and the practical implications of modifying the monitoring protocols. For example, if the analysis demonstrates that the proposed sampling will not achieve the desired level of statistical power, sampling intensity may need to be increased, which could be achieved throughout the duration of the study by adding random sampling stations to the Reference and Impact Areas, by sampling the existing stations more often each month (e.g., three monthly samples, rather than two), or by increasing the duration of the post-construction monitoring.

3.0 Demersal Fisheries Resources Survey – Beam Trawl

Experienced local fishermen report that sections of the Project Area allow for data collection via beam trawl, as beam trawls are smaller and more maneuverable than otter trawls (R. Sykes, pers. comm.). Previous studies have used beam trawls to sample in the vicinity of the Project Area and beam trawls have proven to be an effective gear for sampling demersal species, including juveniles (Malek, 2015; Walsh and Guida, 2017). Based on the data collected by Malek (2015), the beam trawl survey is expected to capture a range of demersal fish and benthic invertebrates that are common to the waters of New England and the mid-Atlantic including sea scallops, summer flounder, windowpane flounder, winter flounder, fourspot flounder, winter skate, little skate, lobster, Jonah crabs, rock crabs, and silver hake.

The beam trawl survey will collect pre- and post-construction data on distribution, abundance and community composition, with a focus on demersal fish and macroinvertebrates species. The primary objective of the beam trawl survey is to evaluate whether the construction and operational activities associated with the Project lead to a significant change in the relative abundance of demersal fish and invertebrates within the Project Area relative to the Reference Areas.

At least two years of sampling (i.e., 24 monthly sampling trips) will be conducted prior to the commencement of offshore construction. The pre-construction monitoring is scheduled to begin in October, 2020. Similarly, a minimum of two years of monitoring will be completed following offshore construction, but the duration of post-construction monitoring will also be informed by ongoing guidance for offshore wind monitoring that is being developed cooperatively through the Responsible Offshore Science Alliance (ROSA).

3.1 Survey Design/Procedures

The survey will be conducted from commercial fishing vessel(s) with scientists onboard to process the catch. Two commercial vessels were selected based on criteria such as experience using a beam trawl, safety record, knowledge of the area, and cost. One vessel will serve as the primary survey vessel, and the other will be used as an alternate. The scientific contractor has applied for an Exempted Fishing Permit (EFP) from NOAA Fisheries in order to use the hired fishing vessel as a scientific platform and conduct scientific sampling that is not subject to the Atlantic Coastal Fisheries Cooperative Management Act, Magnuson-Stevens Fishery Conservation and Management Act, and fishery regulations in 50 CFR parts 648 and 697. All survey activities will be subject to rules and regulations outlined under the MMPA and ESA. Efforts will be taken to reduce marine mammal, sea turtle, and seabird injuries and mortalities caused by incidental interactions with fishing gear. All gear restrictions, closures, and other regulations set forth by take reduction plans (e.g., Harbor Porpoise Take Reduction Plan, Atlantic Large Whale Reduction Plan, etc.) will be adhered to as with typical scientific fishing operations to reduce the potential for interaction or injury.

3.2 Proposed Sampling Stations

As described for the gillnet survey (Section 2.2), an asymmetrical BACI design is proposed for the beam trawl survey to sample within three areas: one survey area within the SFWF Project Area (Figure 4) and two Reference Areas. The Reference Areas were initially identified in 2019, using the same data and process that was described for the gillnet survey (Section 2.2). Due to the complex bathymetry (e.g., hangs and boulders) present in the Project Area and the Reference Areas, a beam trawl survey would be difficult to execute safely using a simple random design. Conversations with fishermen indicate that there is a limited amount of benthic habitat that can be sampled safely and effectively within each area using a beam trawl. Therefore, in lieu of a simple random design, the input of commercial fishermen with experience fishing in these area, and detailed geophysical seafloor survey data, will be used to generate a map of tow tracks that can be safely sampled within the Project Area, and the two Reference Areas. From this map of potential tow tracks, random sampling locations will be selected during each sampling event.

Sampling will occur once per month within the Project and Reference Areas. During each sampling event, three beam trawl lines will be randomly selected from the universe of possible sampling locations in each area, resulting in nine beam trawls conducted per monthly sampling event (*see* Appendix B). This sample size was chosen to provide adequate replication within each area, while considering practical constraints, such as the need to avoid gear conflicts with active fisheries that occur in the Project and Reference Areas, and practical consideration of the amount of sampling that can be accomplished in a day at sea. Sample sizes and sampling strategies may be subsequently modified following the results of a mid-study power analysis (Section 3.7), however the overall sampling design will remain unchanged. During any given sampling event, the location of beam trawl sampling stations may be subject to change due to seasonal location of other fixed fishing gear (e.g., lobster pots). If a survey line is found to have poor conditions for beam trawling it may be moved based on the captain's professional judgement. In this instance an alternate trawling location will be chosen at random from the universe of potential sampling locations within that area.

The fishermen participating in the beam trawl survey provided feedback on the Reference Areas in July 2020. Their feedback indicated that fixed gear and 'broken bottom' is prevalent in portions of the eastern Reference Area that was initially identified in 2019. Based on this feedback, the eastern Reference Area was moved slightly to the north, in order to minimize interactions with fixed gear and broken bottom that may cause operational constraints and safety issues during the beam trawl survey (Figure 4).

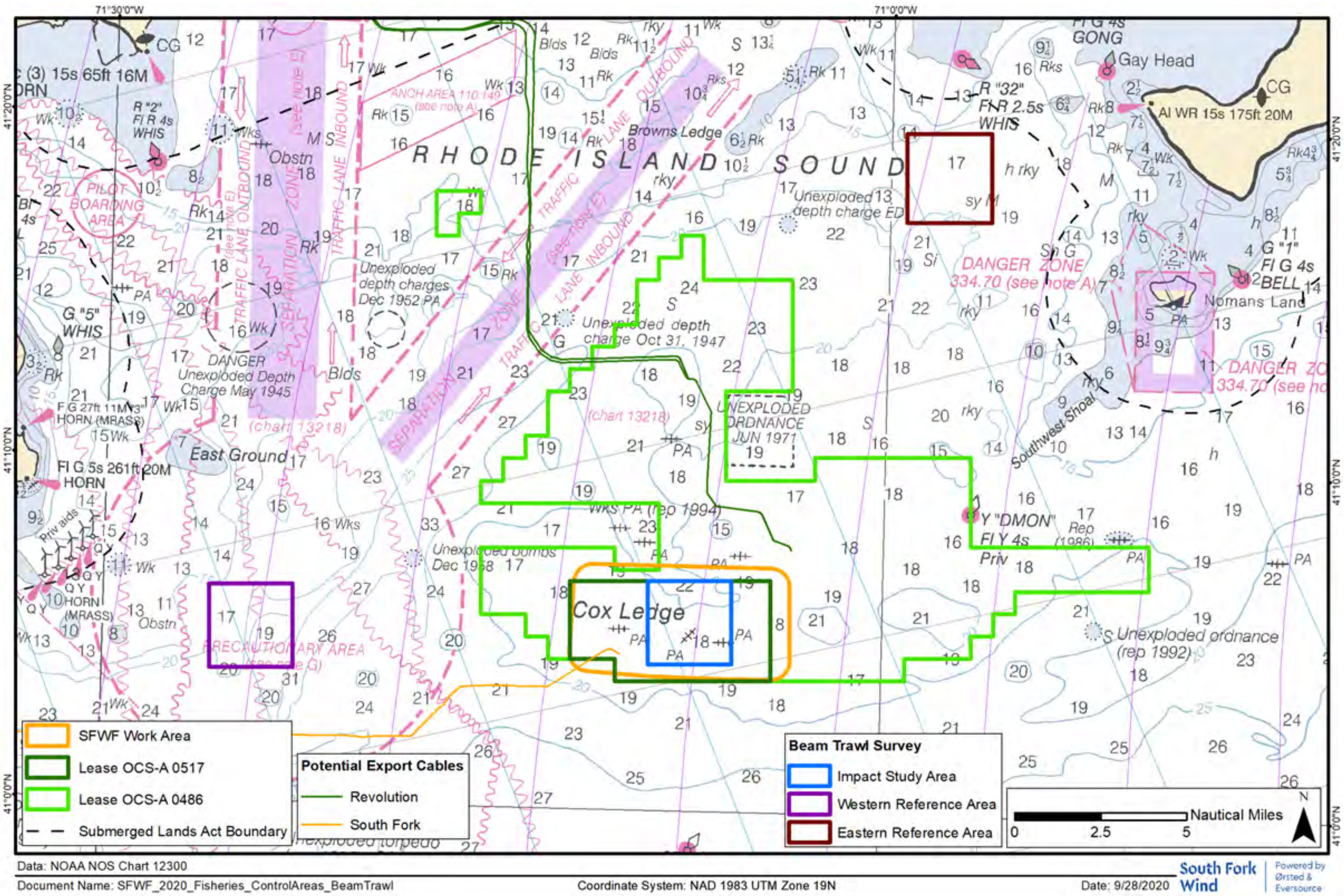

Figure 4. **Northeast lease areas including the South Fork Wind Farm with Beam Trawl Survey Areas.**

3.3 Beam Trawl Methods

Beam trawling will be conducted monthly by a commercial fishing vessel using a 3-m beam trawl, with a cod-end of double 4.75 inch mesh and a 1-inch (2.54-cm) knotless cod end liner (or similar; equivalent to NEAMAP cod end) to ensure retention of the smaller fish (Malek, 2015). A single vessel has been selected as the primary sampling vessel for the survey, and it is planned that this vessel will complete all of the sampling trips. However, an additional vessel has been identified as an alternate, and will be used if problems with the primary vessel preclude it from sampling in a given month. Rock chains will be fitted across the mouth of the beam trawl to prevent larger rocks from entering and damaging the catch or net. Once on station, the crew of the vessel lowers the net into the water fully and allows it to drag behind the boat. When the gear is fully deployed and the winch brakes are set, and the start coordinates, start time, date, tow direction, water depth, and tow speed are recorded. Upon completion of the tow, the end time and coordinates are recorded. At the outset of the survey a target towing speed of 4.0 knots and tow duration of 20 minutes will be used, based on the protocols described by Malek (2015). However, the tow speed and duration may be modified based on feedback received from the captain and scientific crew after initial sampling trips have been completed. The catch from the beam trawl survey will not be retained for sale by the participating vessels, and all animals will be returned to the water as quickly as possible once the sampling is completed.

Fish collected in each tow will be identified, weighed, and enumerated consistent with the sampling approach of NEAMAP. In the case of larger catches, one or multiple subsampling procedures may be used. Subsampling protocols for the beam trawl are adapted from the subsampling procedures of the NEAMAP survey and include straight subsampling by weight, mixed subsampling by weight, and discard by count sampling (Bonzek et al., 2008). The type of sub-sampling strategy that is employed will be dependent upon the volume and species diversity of the catch and will be determined at the discretion of the chief scientist. The scientists will sort and identify fish, and weigh each species according to the following protocol:

All organisms will be identified to species including fish and mega-invertebrates such as sea scallops, squid, lobsters, *Cancer* spp. crabs, sand dollars, and urchins. Taxonomic guides include NOAA's *Guide to Some Trawl-Caught Marine Fishes* (Flescher, 1980), *Bigelow and Schroeder's Fishes of the Gulf of Maine* (Collette and Klein-MacPhee, 2002), Kells and Carpenter's (2011) *Field Guide to Coastal Fishes from Maine to Texas* and *Peterson's Field Guide to the Atlantic Seashore* (Gosner, 1999).

The catch will be sorted by species. In the case of large catches with a range of size classes, the catch may be sorted by relative size categories within each species. The use of size categories is to ensure that all sizes are equally represented in the data if subsampling is used. The chief biologist will determine the categories and approximate length ranges to be used for each species.

The following data elements will be recorded for each tow: total biomass and total number of organisms caught, number and biomass caught for each species, species diversity, and length for dominant species and vulnerable species (e.g., Atlantic sturgeon, thorny skate). Notwithstanding sub-sampling procedures, up to 50 individuals of each species (and size category) are measured and the rest counted. Individual lengths (+/- 0.5 cm) are recorded on the field data sheet. Fork length is recorded for all fishes with a forked tail. Total length is measured for all other fishes. Exceptions to these rules are the measurement of rays (disc width), sharks (straight-line fork length), dogfish (stretched total length), crabs (carapace width), lobsters (carapace length), sea scallops (shell height), and squids (mantle length). Miscellaneous invertebrates (e.g., worms, hermit crabs, snails) will be counted but not measured.

Stomach content analysis will be performed for commercially important species (monkfish, winter skate, winter flounder, gadids) to determine the prey composition for these species during the pre-construction period. Up to 10 animals will be sacrificed for stomach content analyses from each tow that is sampled, with no more than 5 individuals of any one species sampled from each tow. Each fish sampled for stomach content analysis will be measured (+/- 0.5 cm) and weighed (+/- 0.5 g) individually before the stomach is removed to permit assessment of relative condition. All prey items will be identified to the LPIL, counted, and weighed. Atlantic cod are known to spawn on or near Cox Ledge (Zemeckis et al., 2014, Cadrin et al., 2020; Inspire Environmental, 2020). Sex and reproductive stage will be assessed for the cod sacrificed for stomach sampling according to the protocols used for the 2018 and 2019 SFWF Atlantic Cod Spawning Survey (adapted from Burnett et al. [1989] and O'Brien et al. [1993]). Up to five cod may be sampled per tow for sex and maturity and stomach contents. Maturity data from this sampling may be shared with local researchers to better understand the timing and distribution of cod spawning activity in Southern New England.

Should any interactions with protected species (e.g., marine mammals, sea birds, sea turtles) occur, the contracted scientists will follow the sampling protocols described for At-Sea Monitors (ASM) in the Observer On-Deck Reference Guide (Northeast Fisheries Science Center, 2016). Protected species interactions will be reported immediately to NOAA's stranding hotline via telephone (866-755-NOAA) or via the Whale Alert APP, and a follow up detailed written report will be provided to NMFS Greater Atlantic Regional Fisheries Office (incidental.take@noaa.gov) within 24 hours that includes the following information; date, time, area, gear, species, and animal condition and activity. The following protocol will also be followed:

- If a marine mammal take occurs, the entire animal will be retained as time and space allow. However, if there is insufficient space on board the vessel, the minimum sampling requirements described for at-sea monitors will be met.
- If any interactions with Atlantic sturgeon or shortnose sturgeon occur, the contracted scientists will follow the sampling protocols described for the Northeast Fisheries Observer Program (NEFOP) in the Observer On-Deck Reference Guide (Northeast Fisheries Science Center, 2016), which includes collecting a genetic sample and scanning the animal for a PIT tag.
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- If an Atlantic sturgeon or shortnose sturgeon carcass is retained, we will contact Fred Wenzel at the Northeast Fisheries Science Center. Any biological data collected during sampling of protected species will be shared as part of the written report that is submitted to the NMFS Greater Atlantic Regional Fisheries Office.
- Sightings of right whales, and observations of dead marine mammals and sea turtles in the water will be reported immediately to NOAA's stranding hotline via telephone (866-755-NOAA) or via the Whale Alert APP and a follow up detailed written report will be provided to NMFS Greater Atlantic Regional Fisheries Office within 48 hours.
- Sea birds will be sampled following the protocols outlined by the Northeast Fisheries Science Center (2016) and if a dead seabird is encountered, any 'dead, fresh' animals will be retained and provided to the US Fish and Wildlife Service for additional sampling.

- Due to the potential for communicable diseases all physical sampling and handling of marine mammals and seabirds will be limited to the extent Ørsted health and safety assessments and plans allow.

3.4 Environmental Data Collection

Hydrographic data will be collected at each beam trawl sampling location. A Conductivity Temperature Depth (CTD) sensor will be used to sample a vertical profile of the water column at each beam trawl sampling location. The chief scientist will have discretion to decide whether the CTD profile is collected prior to the start of the tow, or at the conclusion of the tow. Bottom water temperature (degrees C) will be recorded at regular intervals (e.g., every 30 seconds) throughout the duration of each beam trawl tow using a temperature logger mounted to the frame of the beam trawl. Sea state and weather conditions are recorded from visual observations. Air temperature may be downloaded from a local weather station if not available onboard.

3.5 Station Data

The following data will be collected during each sampling effort:

- Station number;
- Start latitude and longitude;
- Start time and date;
- Start water depth;
- Tow direction;
- Tow speed;
- Tow duration;
- End latitude and longitude;
- End time and date;
- Wind speed;
- Wind direction;
- Wave height; and
- Air temperature

Vertical CTD profile, and continuous observations of bottom temperature while the gear is fishing (*see* Section 3.4)

3.6 Data Entry and Reporting

Data will be transcribed from hard copy datasheets into electronic worksheets. The data sheets will be reviewed for data entry errors prior to importing into a relational database. Quality control checks will be performed on database tables by running standardized, systematic queries to identify anomalous data values and input errors. Species names (common and scientific) are verified and tabulated for consistency. All data used in analysis will be exported from the relational database.

Annual reports containing catch data will be prepared after the conclusion of each year of sampling and shared with State and Federal resource agencies. One final report will also be produced synthesizing the findings of the pre- and post-construction evaluations.

3.7 Data Analysis

The study will use an asymmetrical BACI experimental design, with statistical evaluation of the differences between reference and Project Areas contrasted in the before and after construction time periods (Underwood, 1994; Smith, 2002). A BACI design will allow for assessment of changes in relative abundance that correlate with proposed construction and operations at the SFWF site.

Results presented in annual reports will focus on comparing the fish and invertebrate communities in the Project Area and the Reference Areas to describe spatial and seasonal differences in relative abundance, species composition, and size distribution. For the dominant species in the catch, seasonal catch per unit effort (CPUE) will be compared among the three areas using graphics and descriptive statistics (e.g., mean and variance). Length frequency data by species will be compared among areas using descriptive statistics, graphical techniques (empirical cumulative distribution function [ECDF] plots), and appropriate statistical tests (e.g., the Kolmogorov-Smirnoff test). Species composition will be compared amongst the Project and Reference Areas using a Bray-Curtis Index and multivariate techniques (e.g., nMDS and ANOSIM).

Analysis presented in the final synthesis report will focus on identifying changes in the fish community in the Project Area between pre- and post- construction that did not also occur at the Reference Areas that could be attributed to either construction or operation of the wind turbines (Table 2). With regard to measuring for changes in relative abundance, the primary research question is to estimate the magnitude of the difference in the temporal changes in relative abundance for the dominant species in the catch observed between the Project and Reference Areas. The null hypothesis is that changes in CPUE (relative abundance) for the dominant species in both the Impact and Reference Areas will be statistically indistinguishable over time. The alternative hypothesis is that changes in CPUE will not be the same at the Impact and Reference Areas over time (two-tailed). Generalized Linear Models (GLMs) will be used to describe the data and estimate the 90% Confidence Interval (CI) on the BACI contrast. The interaction contrast that will be tested is the difference between the temporal change (i.e., average over the post-construction period minus the average over the pre-operation period) at the windfarm and the average temporal change at the Reference Areas. A statistically significant impact would be indicated by a 90% CI for the estimated interaction contrast that excludes zero. Using a 90% CI allows 95% confidence statements for the lower or upper bound (e.g., if the lower bound of the 90% CI for the mean is greater than 0, this indicates 95% confidence that the mean exceeds 0).

For the diet data, the primary question to be asked is whether the construction of the wind farm leads to changes in the diet composition of focal species. The null hypothesis is that changes in diet between the Reference and Impact Areas are statistically indistinguishable over time for the species that are sampled. Monthly diet data for focal species will be obtained from stomach contents, and prey composition will be calculated separately for each species as the mean proportional contribution (W_k) of each prey item (Buckel et al. 1999a; Bonzek et al. 2008) by month and area, where:

$$\%W_k = \frac{\sum_{i=1}^{n} M_i q_{ik}}{\sum_{i=1}^{n} M_i} * 100$$

$$q_{ik} = \frac{w_{ik}}{w_i},$$

and where

n is the total number of beam trawls that collected the fish species of interest,

M_i is the sample size (counts) of that predator species in beam trawl *i*,

w_i is the total weight of all prey items in the stomachs of all fish analyzed from beam trawl *i*, and

w_{ik} is the total weight of prey type *k* in these stomachs.

Potential seasonal differences in prey composition may also be explored for each focal species using multivariate techniques (e.g., nMDS, ANOSIM, and SIMPER). A stomach fullness index (FI) will be calculated for each fish analyzed. The difference between full and empty stomach weights will be determined to obtain the total weight of food (FW). The ingested food weight (FW) is expressed as a percentage of the total fish weight according to a formula defined by Hureau (1969) as cited by Ouakka et al. 2017.

$$FI = FW / \text{fish weight} \times 100$$

Species composition will also be compared between the Before and After periods to determine if the construction and operation of the wind farm had any impacts on the species that are present in the area. Species composition will be compared before and after construction using a Bray-Curtis Index and multivariate techniques (e.g., ANOSIM). Additional data analyses will be performed as appropriate based on the nature of the data that are collected (i.e., normality).

Table 2. Summary of planned analyses for the beam trawl survey.

Design Overview	Design details	Metrics of Interest	Research Question	Post-Construction Statistical Methods
1 Impact, 2 Reference areas; 2 years Before Construction and ≥2 years After Operation; January-December (1x per month)	**Sampling frame** = SFW and Reference areas of similar habitat and size. **Observational unit** = day-area (trawl lines randomized each sampling event; individual trawls are subsamples of day-area estimate). **Response variable** = mean catch per day-area. **Error variance** = temporal	**Catch of dominant and commercially important species**	What is the magnitude of the difference in the temporal changes in the observed metric between SFW and reference areas?	Fit the GLM or GAM that best describes the data; estimate the 90% CI on the BACI contrast.
	Observational unit = sampling event **Response variables** = average abundance of each species **Error variance** = among sampling events	**Species assemblage composition**	How does species composition change over time (B/A), or between areas (C/I)?	Bray-Curtis similarity between sampling events; ANOSIM to identify whether significant differences exist between events from different seasons, years, or locations. Relationships graphically depicted with nMDS.
	Observational unit = individual fish **Response variables** = % contribution (by weight) of each species contributing to total diet/stomach contents. **Error variance** = among individual	**Diet (prey) composition** for key species (e.g., monkfish, winter skate, gadids, black sea bass)	How does diet composition change over time (B/A), or between areas (C/I)?	Bray-Curtis similarity between individual fish; ANOSIM to identify whether significant differences exist between fish from different seasons, years, or locations. Relationships graphically depicted with nMDS.
	Observational unit = individual fish/invertebrate **Response variable** = length **Error variance** = among individual fish/invertebrates	**Length frequency**	How does size structure change over time (B/A)? How does size structure compare between areas (C/I)?	1. descriptive (range, mean) 2. graphical and statistical comparison (between times and locations) of ECDFs using distributional comparison test (e.g., Kolmogorov-Smirnoff).
	Observational unit = individual fish **Response variable** = condition index **Error variance** = among individual fish	**Fish condition index** (i.e., deviations from log-length vs log-weight relationship) by species	What is the magnitude of change in fish condition over time (B/A), or between areas (C/I)?	Find the best fitting model to the condition values by species, and calculate 90% CI of the relevant contrasts.

Definitions:
90% CI = 90% confidence interval
ECDF = empirical cumulative distribution function
nMDS = non-parametric Multidimensional Scaling
ANOSIM = Analysis of Similarities

A power analysis was conducted using data from Malek (2015). These data provided approximate estimates of spatial variability in total abundance among independent tows, but the level of replication over time was insufficient to estimate temporal variability at the scale needed for the power analysis (Appendix B). Therefore, an adaptive sampling strategy will be employed. Upon completion of sampling in 2021, and again following sampling in 2022, a power analysis will be conducted to evaluate the power of the sampling design. The power analysis will be conducted using an approach similar to what was performed for the ventless trap survey (Appendix D). The variance (e.g., RSE) associated with the relative abundance estimates for dominant species in the catch will be calculated. Power curves will be used to demonstrate how statistical power varies as a function of effect size and sample size (i.e., number of beam trawl samples per area). When analyzing changes in the relative abundance of dominant species in the catch, we will aim to attain a statistical power of at least 0.8 to ensure that the monitoring will have a probability of at least 80% of detecting an effect that is present. A single two-tailed alpha (0.10) will be evaluated during the power analysis. There is a direct relationship between the magnitude of the effect size and the statistical power of the analysis, with greater power associated with larger effect sizes.

The results of the power analysis will be considered and can be used to modify the monitoring protocols in subsequent years. The decision to modify sampling will be made after evaluating several criteria including the amount of variability in the data, the statistical power associated with the study design, and the practical implications of modifying the monitoring protocols. For example, if the analysis demonstrates that the proposed sampling will not achieve the desired level of statistical power, sampling intensity may need to be increased, which could be achieved throughout the duration of the study by adding random sampling stations to the Reference and Impact areas, by sampling the existing stations more often each month (e.g., two monthly sampling events, rather than one), or by increasing the duration of the post-construction monitoring.

4.0 Demersal Fisheries Resources Survey – Ventless Trap, Lobster

Lobster and Jonah crab are targeted by fishermen in New England and the Mid-Atlantic and are managed by the Atlantic States Marine Fisheries Commission (ASMFC). Based on recommendations from BOEM's renewable energy fishery guidelines (BOEM, 2013) and stakeholders, this survey will quantify pre-construction data for lobster in the SFWF site (McCann, 2012; Petruny-Parker et al., 2015, MADMF, 2018) such that changes in the resource due to construction and operation of the wind farm can be evaluated. A BACI ventless trap survey will be conducted to collect pre- and post-construction data on lobster and crab resources in the proposed Project Area. The objective of the pre-construction monitoring is to evaluate the spatial and seasonal patterns of relative abundance of lobster, Jonah crab and rock crab in the Project Area and in the Reference Areas. In addition, the proposed study will classify the demographics of lobsters, Jonah crabs, and rock crabs, including size structure, sex ratios, reproductive status, and shell disease. Monitoring will continue after construction to quantify the magnitude of potential changes that may occur to the relative abundance and demographics of lobsters and crabs before and after construction.

At least two years of sampling (i.e., 14 semi-monthly sampling events) will be conducted prior to the commencement of offshore construction. The pre-construction monitoring is expected to commence in May, 2021. Similarly, a minimum of two years of monitoring will be completed following offshore construction, but the duration of post-construction monitoring will also be informed by ongoing guidance for offshore wind monitoring that is being developed cooperatively through the Responsible Offshore Science Alliance (ROSA).

4.1 Survey Design/Procedures

The sampling protocol proposed here is informed by the methods used by the Atlantic States Marine Fisheries Commission (ASMFC) and other regional groups to monitor lobster and crab resources in the region (Wahle et al., 2004; O'Donnell et al., 2007; Geraldi et al., 2009; Collie and King, 2016). While the current survey is focused upon SFWF, we also plan to conduct similar ventless trap monitoring at the adjacent Revolution lease area. Further, as part of an effort to standardize monitoring amongst offshore wind developers, the sampling methodologies proposed here are similar to sampling methods being used at the Vineyard Wind development site. All sampling will occur on commercial lobster vessels that are chartered by Commercial Fisheries Research Foundation and the University of Rhode Island for the survey.

The scientific contractors have applied for an EFP from NOAA Fisheries in order to use the commercial lobster vessels as a scientific platform and conduct scientific sampling that is not subject to the Atlantic Coastal Fisheries Cooperative Management Act, Magnuson-Stevens Fishery Conservation and Management Act, and fishery regulations in 50 CFR parts 648 and 697. All survey activities will be subject to rules and regulations outlined under the MMPA and ESA. Efforts will be taken to reduce marine mammal, sea turtle, and seabird injuries and mortalities caused by incidental interactions with fishing gear. All gear restrictions, closures, and other regulations set forth by take reduction plans (e.g., Harbor Porpoise Take Reduction Plan, Atlantic Large Take Whale Reduction Plan, etc.) will be adhered to as with typical scientific fishing operations to reduce the potential for interaction or injury.

The requirements described in the Atlantic Large Whale Take Reduction Plan (NOAA, 2018b) for the trap and pot fisheries will be followed. At a minimum, the following measures will be used to avoid interactions between the ventless trap survey and marine mammals, although additional gear modifications can be made at the discretion of NOAA:

- No buoy line will be floating at the surface.
- There will not be wet storage of the gear. All sampling gear will be hauled at least once every 30 days, and all gear will be removed from the water at the end of each sampling season.
- All groundlines will be constructed of sinking line.
- Fishermen contracted to perform the field work will be encouraged to use knot-free buoy lines.
- All buoy line will use weak links that are chosen from the list of NMFS approved gear.
- All buoys will be labeled as research gear, and the scientific permit number will be written on the buoy. All markings on the buoys and buoy lines will be compliant with the regulations. Gear will be marked according to instructions received from the Greater Atlantic Regional Fisheries Office.
- Missing line or trawls will be reported to the NOAA Protected Resources Division as quickly as possible.
- Further modifications to the sampling gear can be made at the discretion of the Greater Atlantic Regional Fisheries Office.

4.2 Sampling Stations

The ventless trap lobster survey will be conducted using an asymmetrical BACI experimental design, with quantitative comparisons made before and after construction and between reference and Project Areas (Underwood, 1994). We collaborated with the scientific contractors and participating fishermen that have been selected to perform the fisheries monitoring to select two Reference Areas for this survey (Figure 5), following the considerations described in Section 2.2. The two Reference Areas that were selected have similar bottom types, benthic habitat, and areal extent as the SFWF site. Data collected at the Reference Areas will serve as a regional index of lobster, rock crab, and Jonah crab abundance in locations outside of the direct influence of the Project.

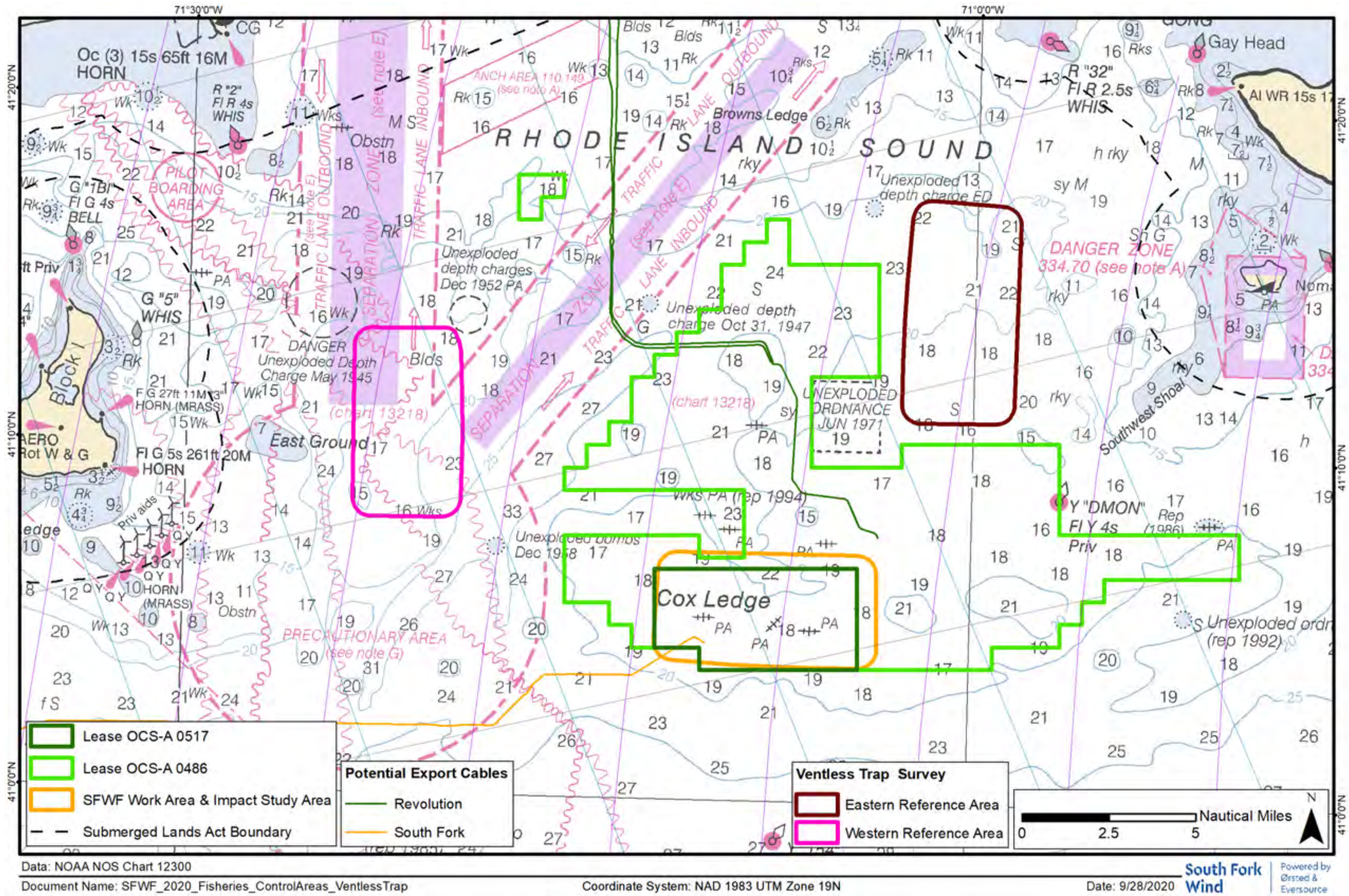

Figure 5. Northeast lease areas including the South Fork Wind Farm with Ventless Trap Survey Areas.

Sampling stations in the Project and Reference Areas will be allocated using a spatially balanced random design, with ten trawls (10 traps per trawl) deployed in each of the thee areas during each sampling event. The protocols proposed for the survey as consistent with those used during the Southern New England Cooperative Ventless Trap Survey (SNECVTS; Collie and King, 2016). The Project Area and Reference Areas will each be divided into a series of ten grid cells. Each grid cell will be further divided into aliquots (Figure 6). Through consultation with local industry members, a subset of the aliquots within each grid cell will be identified as suitable sampling sites based on the desire to minimize gear conflicts amongst fishermen in the area. At the beginning of each sampling season, an aliquot will be randomly selected for sampling within each grid cell. An alternative aliquot will also be selected within each grid cell, and the alternative aliquot will be sampled if needed based on local conditions (e.g., to avoid gear conflicts).

To achieve consistency with the ASMFC and SNECVTS protocols, the stations will be selected randomly at the start of each year of sampling, and the sampling locations will remain fixed for the remainder of the year. This sampling approach keeps the station occupied, reduces time spent moving traps between locations, and is generally similar to the routine operations of lobstermen in the region. To minimize gear interactions with other user groups in these areas, the lead scientist will work with the captain to ensure that the gear is set in accordance with local fishing practices.

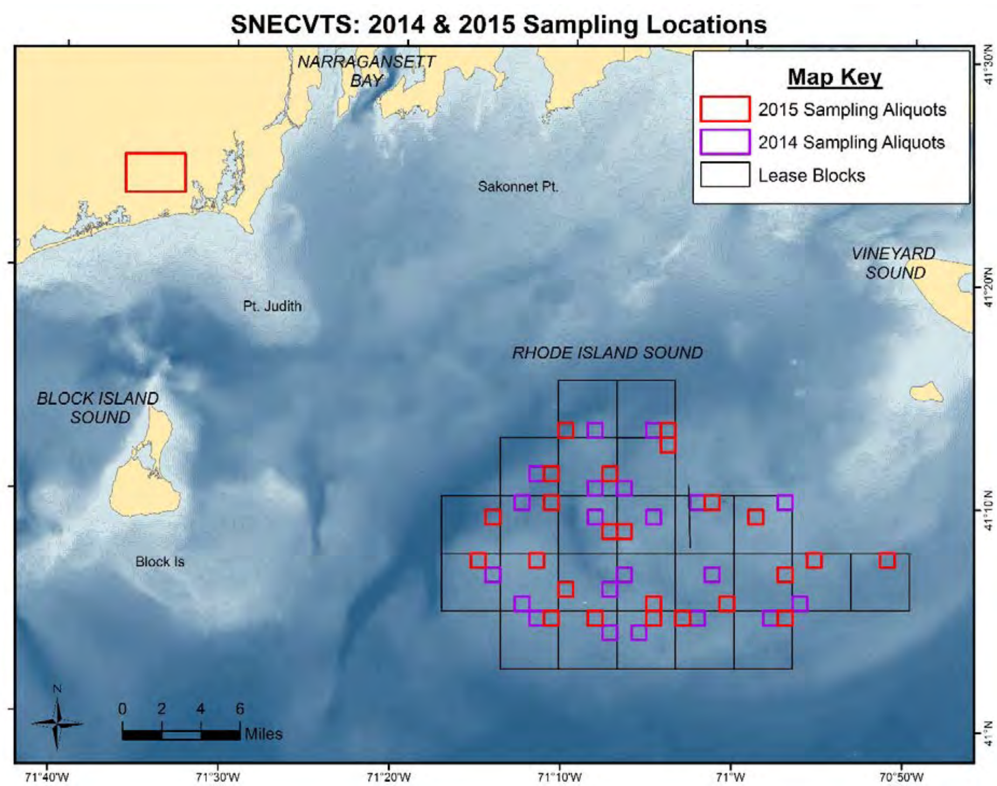

Figure 6. Example of the station selection method employed during the Southern New England Cooperative Ventless Trap Survey. The study area was stratified into 24 sampling grid cells, and each grid cell was further divided into aliquots. One aliquot from each grid was randomly selected for sampling in each year. Figure from Collie and King (2016).

4.3 Ventless Trap Methods

Lobster and crab resources in SFWF and the Reference Areas will be surveyed using commercial lobster vessels with scientists onboard to process the catch. Local lobster vessels have been contracted to conduct the sampling using a trap that is consistent with that used in the ASMFC and SNECVTS ventless trap surveys. This trap is a single parlor trap, 16 inches high, 40 inches long, and 21 inches wide with 5-inch entrance hoops and is constructed with 1-inch square rubber coated 12-gauge wire. The trap is constructed with a disabling door that can close off the entrance during periods between samples when the trap is on the bottom but not sampling. Local fishermen provided input that fishing longer trawls (i.e., 10 pot vs., 6 pot) should reduce the likelihood of gear losses during the study. Trawls will be configured with 10 traps on each trawl – six ventless (v) and four vented (or standard, S) in the following pattern: V-S-V-S-V-V-S-V-S-V; this is consistent with the gear configuration used in the SNECVTS (Collie and King, 2016). One trawl will be set in each of the 10 grid cells within the Project Area and two Reference Areas, for a total sampling intensity of 30 trawls (300 traps) per bimonthly sampling event. A power analysis based the data collected during the SNECVTS in 2014 and 2015 was completed to estimate the statistical power associated with this sampling design (*see* Appendix D for details). The results of the power analysis suggested that given a small to moderate effect size (0.25) the proposed BACI sampling design should have a statistical power of >0.8 to detect changes in the relative abundance of lobster, rock crabs, and Jonah crabs.

A temperature logger (Onset TidBit or similar) will be attached to the first trap in each trawl to record water temperature continuously throughout the monitoring period. A Conductivity Temperature Depth (CTD) sensor will be used to sample a vertical profile of the water column at each station.

Pre-construction sampling will occur twice per month from May through November. The sampling period of May through November was derived from a combination of feedback from commercial fishermen and to establish consistency with existing regional surveys (Rhode Island Department of Environmental Management [RIDEM], Massachusetts Division of Marine Fisheries [MADMF], SNECTVS). The standard soak time will be five nights, which is consistent with local fishing practices to maximize catch, and congruent with the protocols used on the SNECVTS survey. Soak time will remain consistent throughout the duration of the survey, to the extent practicable. Traps will be baited with locally available bait. At the start of each monthly sampling event, the lobsterman will retrieve and bait the traps. After the five-day soak period, the traps will be hauled and the catch will be processed for sampling, and the traps will be rebaited for another five-night soak. Each survey event will be managed by a team of qualified scientists including a lead scientist with experience performing lobster research. The catch will be removed from the traps by the vessel crew for processing. The lead scientist will be responsible for collection and recording of all data. The catch from the ventless trap survey will not be retained for sale by the participating vessels, and all animals will be returned to the water as quickly as possible once the sampling is completed.

The catch will be processed in a manner consistent with the ASMFC and SNECVTS ventless trap surveys. The following data elements will be collected for each trawl sampled during the survey; total number and biomass of individuals sampled, number and biomass for each species, and length of dominant invertebrate species (lobster, Jonah crab, and rock crab) and fish (+/- 0.5cm) that are captured in the traps. Data collected for individual lobsters will include:

- Carapace length: Measured to the nearest mm using calipers.
- Sex: Determined by examining the first pair of swimmerets.

- Eggs: Examine the underside of the carapace for the presence or absence of eggs.
- V-notch status: present or absent
- Cull status: Examine the claws for condition (claws missing, buds, or regenerated)
- Incidence of shell disease: absent, moderate, or severe
- Mortality: alive or dead

Biological information will also be collected for Jonah crabs and rock crabs. One ventless trap will be randomly selected in each string, and biological data will be recorded for all of the Jonah crabs and rock crabs that are captured in that randomly selected ventless trap. Counts and weights will be recorded for Jonah crabs and rock crabs from the other nine traps in each string. The following data elements will be recorded for each rock crab and Jonah crab that are sampled in the one randomly selected ventless trap in the trawl:

- Carapace width: Measured to the nearest mm using calipers.
- Sex: Determined by examining the width of the abdomen (apron). For female crabs, it is noted that there will be small differences in the width of the abdomen between mature and immature animals.
- Ovigery status: Presence/absence of eggs. Egg color recorded for females with eggs present.
- Incidence of shell disease: absent or present (3 categories: 1-10%, 11-50%, >50%)
- Cull status: Examine the claws for condition (claws missing, buds, or regenerated)
- Mortality: alive or dead

Should any interactions with protected species (e.g., marine mammals, sea birds, sea turtles) occur, the contracted scientists will follow the sampling protocols described for At-Sea Monitors (ASM) in the Observer On-Deck Reference Guide (Northeast Fisheries Science Center, 2016). Protected species interactions will be reported immediately to NOAA's stranding hotline via telephone (866-755-NOAA) or via the Whale Alert APP, and a follow up detailed written report will be provided to NMFS Greater Atlantic Regional Fisheries Office (incidental.take@noaa.gov) within 24 hours that includes the following information; date, time, area, gear, species, and animal condition and activity. The following protocols will also be followed:

- If a marine mammal take occurs, the entire animal will be retained as time and space allow. However, if there is insufficient space on board the vessel, the minimum sampling requirements described for at-sea monitors will be met.
- If any interactions with Atlantic sturgeon or shortnose sturgeon occur, the contracted scientists will follow the sampling protocols described for the Northeast Fisheries Observer Program (NEFOP) in the Observer On-Deck Reference Guide (Northeast Fisheries Science Center, 2016), which includes collecting a genetic sample and scanning the animal for a PIT tag.
- Interactions with sturgeon will be reported immediately to NOAA's stranding hotline via telephone (866-755-NOAA) or via the Whale Alert APP, and a follow up detailed written report will be provided to NMFS Greater Atlantic Regional Fisheries Office within 24 hours.

- If an Atlantic sturgeon or shortnose sturgeon carcass is retained, we will contact Fred Wenzel at the Northeast Fisheries Science Center. Any biological data collected during sampling of protected species will be shared as part of the written report that is submitted to the NMFS Greater Atlantic Regional Fisheries Office.
- Sightings of right whales, and observations of dead marine mammals and sea turtles in the water will be reported immediately to NOAA's stranding hotline via telephone (866-755-NOAA) or via the Whale Alert APP and a follow up detailed written report will be provided to NMFS Greater Atlantic Regional Fisheries Office within 48 hours.
- Sea birds will be sampled following the protocols outlined by the Northeast Fisheries Science Center (2016) and if a dead seabird is encountered, any 'dead, fresh' animals will be retained and provided to the US Fish and Wildlife Service for additional sampling.
- Due to the potential for communicable diseases all physical sampling and handling of marine mammals and seabirds will be limited to the extent Ørsted health and safety assessments and plans allow.

4.4 Environmental Data

Hydrographic data will be collected at each trawl that is sampled. A Conductivity Temperature Depth (CTD) sensor will be used to sample a vertical profile of the water column at each ventless trap sampling location, following the methods used by the CFRF/WHOI Shelf Research Fleet (Gawarkiewicz and Malek Mercer, 2019). The CTD profile may be collected either before the first trap in each trawl is hauled, or after the last trap in the trawl is hauled, at the discretion of the chief scientist. Bottom water temperature (degrees C) will be recorded at regular intervals (e.g., every 30 seconds) throughout the duration of each trawl deployment set using a temperature logger mounted on the first trap in each trawl.

4.5 Ventless Trap Station Data

The following data will be collected during each sampling effort:

- Station number;
- Start latitude and longitude;
- Start time and date;
- Start water depth;
- End latitude and longitude;
- End time and date;
- Wind speed;
- Wind direction;
- Wave height;
- Air temperature;
- Type of bait that was used; and

- Vertical CTD profile, and continuous observations of bottom temperature while the gear is fishing (Section 4.4).

4.6 Data Management and Analysis

The ventless trap survey will supplement the available pre-construction data on lobster and crab resources in the proposed SFWF site (i.e., SNECVTS survey dataset). The pre-construction monitoring data will be analyzed to evaluate the spatial and seasonal patterns of relative abundance of lobster, Jonah crab and rock crabs in the Project and Reference Areas. Results reported in annual reports will focus on comparing relative abundance, size frequencies, and demographic parameters between the Project and Reference Areas. For lobster, Jonah crab, and rock crab, CPUE (average annualized catch per trawl) will be compared amongst the Project and Reference Areas using descriptive statistics (e.g., mean, variance and range); and length frequency data by species will be compared among areas using descriptive statistics, graphical techniques (eCDF plots), and appropriate statistical tests (e.g., Kolmogorov-Smirnoff tests). Sex ratios will be reported for each sampling event for each area and compared amongst areas. The abundance and distribution of lobster, Jonah crab, and rock crab will be mapped each month, and descriptive statistics will be used to report on monthly trends in biological information such as shell disease or egg status.

Sampling after construction will allow for quantification of changes in the relative abundance and demographics of the lobster and crab resources due to construction activities as well as operation of the windfarm. For lobster, Jonah crab, and rock crab, the primary research question is the magnitude of difference in the temporal changes in relative abundance that are observed between the Project and Reference Areas. The null hypothesis for this design is that the changes in relative abundance in both the Project and Reference Areas will be statistically indistinguishable over time for lobster, Jonah crabs, and rock crabs. The alternative hypothesis is that changes in CPUE will not be the same at the Impact and Reference Areas over time (two-tailed). GLMs or GAMs will be used to describe the data and estimate the 90% Confidence Interval (CI) on the interaction contrast (Table 3). The interaction contrast that will be tested is the difference between the temporal change (i.e., average over the post-operation period minus the average over the pre-operation period) at the windfarm and the average temporal change at the Reference Areas. A statistically significant impact would be indicated by a 90% confidence interval for the estimated interaction contrast that excludes zero.

Spatial and temporal patterns in the biological data for lobsters and crabs (shell disease, sex ratios, reproductive status) will be summarized and reported. Similar to the methods described for relative abundance, GLMs or GAMs may also be used to test for the magnitude of the difference in the temporal change between the Project and Reference Areas for the biological parameters that will be collected (e.g., shell disease, cull status). The null hypothesis is that changes in demographic parameters (e.g., shell disease) for lobsters and crabs in both the Reference and Impact Areas will be statistically indistinguishable over time. The alternative hypothesis is that changes in demographic parameters will not be the same at the Reference and Impact Areas over time (two-tailed). GLMs or GAMs will be used to describe the data and estimate the 90% Confidence Interval (CI) on the interaction contrast. The interaction contrast that will be tested is the difference between the temporal change (i.e., average over the post-operation period minus the average over the pre-operation period) at the windfarm and the average temporal change at the References Areas. A statistically significant impact would be indicated by a 90% confidence interval for the estimated interaction contrast that excludes zero.

Table 3. Summary of the planned analyses for the ventless trap survey.

Design Overview	Design details	Metrics of Interest	Research Question	Post-Construction Statistical Methods
1 Impact, 2 Reference areas; 2 years Before Construction and ≥2 years After Operation; May-November (2x per month); 5-day soak time.	**Sampling frame** = SFW and Reference areas of similar habitat and size. **Observational unit** = Trawl (trawl locations randomized for first sampling event of each year, then fixed for remainder of year). **Response variable** = annual mean CPUE per trawl. **Error variance** = among replicate trawls within year and area.	**Lobster**: catch, ovigery rates, ovigery status, shell disease, cull status; **Jonah crab**: catch, ovigery status (color code eggs), shell disease; **Rock crab**: catch, ovigery status (color code eggs), shell disease	What is the magnitude of the difference in the temporal changes in the observed metric between SFW and reference areas?	Fit the GLM or GAM that best describes the data; estimate the 90% CI on the BACI contrast.
	Observational unit = individual fish/invertebrates **Response variable** = length **Error variance** = among individual fish/invertebrates	**Length frequency**	How does size structure change over time (B/A)? How does size structure compare between areas (C/I)?	1. descriptive (range, mean) 2. graphical and statistical comparison (between times and locations) of ECDFs using distributional comparison test (e.g., Kolmogorov-Smirnoff).

Definitions:
90% CI = 90% confidence interval
ECDF = empirical cumulative distribution function

5.0 Demersal Fisheries Resource Survey – Ventless Fish Pot

Black sea bass, scup, and tautog are important target species in both the commercial and recreational fisheries in southern New England and the Mid-Atlantic. Black sea bass and scup are jointly managed by the Mid-Atlantic Fisheries Management Council (MAFMC) and the Atlantic States Marine Fisheries Commission (ASMFC), while tautog are managed by the ASMFC. Black sea bass and tautog are typically associated with complex bottom habitats and not often well represented in trawl survey catches. There is also a significant pot fishery for these species in the region. Therefore, a fish pot survey will be a suitable gear type for monitoring these species at SFWF. The emphasis on sampling for black sea bass is justified given that this species has Essential Fish Habitat (EFH) throughout the Project Area and is considered to be vulnerable to potential habitat disturbance from offshore wind construction and operation activities (Guida et al., 2017).

Fish pots are a transportable, cage-like, stationary fishing gear, which typically use bait as an attractant for target species, along with retention devices to prevent the escape of captured individuals (Suuronen et al., 2012). Fish pots possess many characteristics that are desirable in a sampling gear: they can be highly selective for targeted species, and fish can generally be returned after sampling in healthy condition and with low rates of post-capture mortality (Bjordal, 2002; Pol and Walsh, 2005; ICES, 2006; Rotabakk et al., 2011). Fish pots also provide an alternative survey and harvest method for areas inaccessible to otter-trawling, such as reefs and other hard bottom habitats (ICES, 2009; Petruny-Parker et al., 2015). As static gears, pots exhibit low impact to habitats (Thomsen et al., 2010).

Fish pots are often designed to target specific species, or subgroupings of species. This is accomplished through the structural design of the pot openings, the pot holding areas, and the bait selected to attract species. Due to these characteristics, pots do not provide a comprehensive assessment of fish and invertebrates in a study area. However, they do provide important additional sampling data in areas where bottom trawling is not an option. In addition, as a static gear, fish pots are well-suited for sampling along a spatial gradient, particularly in close proximity to the turbine foundations.

The SFWF fish pot survey will be conducted to determine the spatial scale of potential impacts on the abundance and distribution of juvenile and adult fish, particularly black sea bass, scup, and tautog, within the proposed SFWF site. The main question to be addressed is whether the relative abundance and distribution of these three species changes before and after construction. In particular, we are interested in determining whether the areas closest to the turbine foundations demonstrate increased relative abundance of these structure-oriented species following construction. An increase in abundance would be suggestive of a 'reef effect', whereby the addition of offshore wind foundations and scour protection creates new habitat for fish, which leads to subsequent increases in abundance in the Project Area (Anderson and Ohman, 2010; Bergstrom et al., 2013). This 'reef effect' has been documented in roughly half of the offshore wind farm monitoring studies that have tested for this impact (Glarou et al., 2020).

In particular, black sea bass are a suitable focal species to assess questions related to introduced habitat. Black sea bass may be associated with relatively shallow, complex habitats that are characterized by placed materials (i.e., artificial reefs; Fabrizio et al., 2013b). Black sea bass off the coast of New Jersey appeared to use artificial reefs primarily for shelter, rather than for feeding (Steimle and Figley, 1996). Previous research has shown that black sea bass (especially adult males) on complex habitats generally exhibit relatively small home ranges, and typically exhibit limited movements during the summer months (<0.1km/day; Moser and Shepherd, 2009; Fabrizio et al., 2013a).

At least two years of sampling (i.e., 14 monthly sampling events) will be conducted prior to the commencement of offshore construction. It is anticipated that the fish pot survey will commence in April, 2021. Similarly, a minimum of two years of monitoring will be completed following offshore construction, but the duration of post-construction monitoring will also be informed by ongoing guidance for offshore wind monitoring that is being developed cooperatively through the Responsible Offshore Science Alliance (ROSA).

5.1 Survey Design/Procedures

A Before-After-Gradient (BAG) survey will be conducted at SFWF using fish pots to assess the spatial scale and extent of wind farm effects on habitat preferred by structure associated species like black sea bass, scup, and tautog. The survey will be conducted from commercial fishing vessels with scientists onboard to process the catch. Local commercial fishing vessels were selected based on criteria such as experience, safety record, knowledge of the area, and cost. The scientific contractor has applied for an EFP from NOAA Fisheries in order to use the hired fishing vessels as a scientific platform and conduct scientific sampling that is not subject to the Atlantic Coastal Fisheries Cooperative Management Act, Magnuson-Stevens Fishery Conservation and Management Act, and fishery regulations in 50 CFR parts 648 and 697. All survey activities will be subject to rules and regulations outlined under the MMPA and ESA. Efforts will be taken to reduce marine mammal, sea turtle, and seabird injuries and mortalities caused by incidental interactions with fishing gear. All gear restrictions, closures, and other regulations set forth by take reduction plans (e.g., Harbor Porpoise Take Reduction Plan, Atlantic Large Whale Reduction Plan, etc.) will be adhered to as with typical scientific fishing operations to reduce the potential for interaction or injury.

The requirements described in the Atlantic Large Whale Take Reduction Plan (NOAA, 2018b) for the trap and pot fisheries will be followed. At a minimum, the following measures will be used to avoid interactions between the fish pot survey and marine mammals, although additional modifications to the sampling gear can be made at the discretion of NOAA:

- No buoy line will be floating at the surface.
- There will not be wet storage of the gear. All sampling gear will be hauled at least once every 30 days, and all gear will be removed from the water at the end of each sampling season.
- All groundlines will be constructed of sinking line.
- Fishermen contracted to perform the field work will be encouraged to use knot-free buoy lines.
- All buoy line will use weak links that are chosen from the list of NMFS approved gear.
- All buoys will be labeled as research gear, and the scientific permit number will be written on the buoy. All markings on the buoys and buoy lines will be compliant with the regulations. Gear will be marked according to instructions received from the Greater Atlantic Regional Fisheries Office.
- Further modifications to the sampling gear can be made at the discretion of the Greater Atlantic Regional Fisheries Office.

5.2 Sampling Stations

To accomplish the goals of this survey, data will be collected before and after installation and operation of SFWF using a BAG survey design. The study design will sample at increasing distances from turbine locations to examine the spatial scale of effects from construction and operation of a turbine on the surrounding habitat and associated fish species (Ellis and Schneider, 1997). The proposed survey design eliminates the need for a Reference Area as is typical in a BACI design. Sampling effort is focused on sampling sites along a spatial gradient within the work area, rather than using a control location that may not be wholly representative of the conditions within the work area (Methratta, 2020). This design also allows for the examination of spatial variation and does not assume homogeneity across sampling sites within the Project Area (Methratta, 2020).

The methodologies and sampling distances employed in previous offshore wind studies were considered in the design of the fish pot survey. Transect studies using visual observations of SCUBA divers have been able to compare fish densities immediately adjacent to the turbine with nearby locations (e.g., 0m vs. 20m; Wilhelmson et al., 2006; Anderson and Ohman, 2010). Bergstrom et al (2013) used fyke nets to sample along transects that spanned a distance range of 20 to 1350m from a turbine foundation and observed that four of the seven fish species examined demonstrated increased densities near the turbine. Griffin et al., (2016) used Baited Remote Underwater Video (BRUVs) to compare fish abundance and species assemblage at locations adjacent to the turbine foundation with locations 100m from turbine foundations in the Irish Sea. Lefaible et al (2019) used grab sampling to classify macrobenthic communities and sampled at two distance categories from the foundations (‘very close’ = 37.5m and ‘far’ = 350-500m). Using gillnets, Stenberg et al (2015) sampled at three increasing distance categories from the turbine foundations (‘near’ = 0-100m, ‘middle’ = 120-200m, and ‘far’ = 230-330m) and demonstrated that fish with an affinity to rocky habitats were most abundant close to the turbine foundations, while the opposite effect was observed for whiting. In a review paper based on European case studies, Methratta (2020) noted that the majority of direct effects associated with turbine foundations (e.g., habitat provision, attraction, food provision) are expected to occur on a local scale (i.e., 10 - 100s of meters from the turbine foundation). Artificial reef studies also offer some information to inform the sampling strategy. For example, Rosemond et al. (2018) compared fish biomass and species richness using SCUBA between artificial reefs and adjacent sandy habitats and found that the abundance and species richness of fish was highest on the reefs and gradually declined across adjacent sand habitats from 30m to 120m away from the reef. It is important to note that many of the studies referenced above investigated wind farms that were built on relatively homogenous habitats (e.g., sand). Given the availability of naturally occurring complex habitat (e.g., boulders and ledge) within SFWF, it is uncertain whether the introduction of novel habitat associated with the turbine foundation and scour protection will cause a detectable change in abundance or distribution for these structure-oriented species.

Eight turbine locations will be randomly selected for sampling prior to the first year of the survey. Those turbines and trawl positions will remain fixed for the duration of the survey (preconstruction and post-construction). Each trawl will be 900 meters in length. The length of the trawl was chosen to cover approximately half of the distance between adjacent turbines. The turbines will be positioned in a grid pattern, with one nautical mile of spacing between adjacent turbines. The intent of choosing this trawl length was to ensure that there was adequate sampling of both the habitat in the close proximity of a turbine foundation, while also sampling areas within the wind farm where the habitat will not be altered for comparison. During the pre-construction monitoring, the first trap of the trawl will be placed within the buffer zone around the planned location of turbine, and the trawl will be set in a straight line extending away from the turbine. During the post-construction monitoring, the first pot of the string will be placed as close to the turbine foundation as possible (given safety considerations) to sample the habitat immediately adjacent to the turbine.

Each trawl will have 18 pots. The spacing between pots along the length of each trawl will not be identical; and the pot spacing intervals were selected based on information about the home range of black sea bass and consideration was also given to the results of prior offshore wind monitoring studies discussed above which often showed that the greatest effects on abundance and distribution occurred in close proximity to the turbine foundation. Using acoustic telemetry, Fabrizio et al (2013) reported a median home range for black sea bass (of unknown sex) of 137 hectares (436,085m^2), at an artificial reef off New Jersey. If it is assumed that the foundation of the turbine serves as the focal point for the home range of a sea bass (post-construction), then the home range can be represented by a circle with a radius of 660m. The first five fish pots will sample within 50m of the turbine foundation at 10m intervals (e.g., 10, 20, 30, 40, and 50m from the turbine). The intention is to intensely sample the locations directly adjacent to the turbine foundation, where the greatest effects on fish abundance and distribution would be anticipated. The remaining thirteen fish pots will be spaced 65m apart and will sample at distances of approximately 115m to 900m from the turbine foundation. The intent is to sample in areas of the wind farm that are both within and beyond the assumed median home range of black sea bass (Fabrizio et al., 2013), and also sample at distances that are outside of any habitat alteration associated with the installation of the turbine foundation and the addition of the scour protection. To minimize gear interactions with other user groups in these areas, the lead scientist will work with the captain to ensure that the gear is set in accordance with local fishing practices.

5.3 Fish Pot Methods

The fish pot survey will be conducted using typical rectangular fish pots commonly used in Rhode Island and Massachusetts fisheries and these fish pots are also used in other regional pot surveys (R. Balouskus, RIDEM, pers comm.). The ventless fish pots measure 43.5 inches long, 23 inches wide, and 16 inches high and are made from 1.5-inch coated wire mesh. Each pot will be baited with whole clam bellies and the entire trawl allowed to soak for 24 hours. Sampling will take place once per month from April through October. The Contractor selected to carry out the survey will take efforts to ensure that the timing of sampling is approximately consistent within each month, to the extent practicable. Soak time will remain consistent throughout the duration of the survey. Each survey event will be managed by a team of qualified scientists including a lead Scientist with experience performing fisheries research. The catch will be removed from the pots by the boat crew for processing. The Lead scientist will be responsible for collection of data and data recording. The catch from the fish pot survey will not be retained for sale by the participating vessels, and all animals will be returned to the water as quickly as possible once the sampling is completed.

Fish collected in each pot will be identified to species, weighed, and enumerated. The following data elements will be recorded for each fish pot; total biomass and total number of organisms caught, number and biomass caught for each species, number of species, and length for species caught. Subsampling for length may occur, at the discretion of the chief scientist, if there is a large number of fish captured in a given pot.

The catch from each pot will be sorted by species and size (if appropriate) into baskets or fish totes as needed. This process continues until all animals are sorted, and the chief biologist verifies that the sorting areas are clear of all animals. Notwithstanding sub-sampling procedures, up to 50 individuals of each species/size are measured (+/- 0.5 cm) and the rest counted. A subset of the individual fish that are measured will also be weighed (+/- 5.0g) to evaluate individual fish condition. Fork length is recorded for all fishes with a forked tail. Total length is measured for all other fishes. Dominant invertebrate species will be measured as follows: crabs (carapace width) and lobsters (carapace length). Miscellaneous invertebrates (e.g., worms, hermit crabs, snails) will be counted but not measured.

Should any interactions with protected species (e.g., marine mammals, sea birds, sea turtles) occur, the contracted scientists will follow the sampling protocols described for At-Sea Monitors (ASM) in the Observer On-Deck Reference Guide (Northeast Fisheries Science Center, 2016). Protected species interactions will be reported immediately to NOAA's stranding hotline via telephone (866-755-NOAA) or via the Whale Alert APP, and a follow up detailed written report will be provided to NMFS Greater Atlantic Regional Fisheries Office (incidental.take@noaa.gov) within 24 hours that includes the following information; date, time, area, gear, species, and animal condition and activity. The following protocols will also be followed:

- If a marine mammal take occurs, the entire animal will be retained as time and space allow. However, if there is insufficient space on board the vessel, the minimum sampling requirements described for at-sea monitors will be met.
- If any interactions with Atlantic sturgeon or shortnose sturgeon occur, the contracted scientists will follow the sampling protocols described for the Northeast Fisheries Observer Program (NEFOP) in the Observer On-Deck Reference Guide (Northeast Fisheries Science Center, 2016), which includes collecting a genetic sample and scanning the animal for a PIT tag.
- Interactions with sturgeon will be reported immediately to NOAA's stranding hotline via telephone (866-755-NOAA) or via the Whale Alert APP, and a follow up detailed written report will be provided to NMFS Greater Atlantic Regional Fisheries Office within 24 hours.
- If an Atlantic sturgeon or shortnose sturgeon carcass is retained, we will contact Fred Wenzel at the Northeast Fisheries Science Center. Any biological data collected during sampling of protected species will be shared as part of the written report that is submitted to the NMFS Greater Atlantic Regional Fisheries Office.

- Sightings of right whales, and observations of dead marine mammals and sea turtles in the water will be reported immediately to NOAA's stranding hotline via telephone (866-755-NOAA) or via the Whale Alert APP and a follow up detailed written report will be provided to NMFS Greater Atlantic Regional Fisheries Office within 48 hours.
- Sea birds will be sampled following the protocols outlined by the Northeast Fisheries Science Center (2016) and if a dead seabird is encountered, any 'dead, fresh' animals will be retained and provided to the US Fish and Wildlife Service for additional sampling.
- Due to the potential for communicable diseases all physical sampling and handling of marine mammals and seabirds will be limited to the extent Ørsted health and safety assessments and plans allow.

5.4 Environmental Data

Hydrographic data will be collected at sampling location. A Conductivity Temperature Depth (CTD) sensor will be used to sample a vertical profile of the water column at each fish pot sampling location. The CTD may be collected either before the first fish pot in each trawl is hauled, or after the last pot in the trawl is hauled, at the discretion of the chief scientist. A temperature logger (Onset TidBit or similar) will be attached to the first fish pot on each trawl to record water temperature continuously throughout the monitoring period. Sea state and weather conditions are recorded from visual observations. Air temperature may be downloaded from a local weather station if not available onboard.

5.5 Fish Pot Station Data

The following data will be collected during each sampling effort:

- Station number;
- Start latitude and longitude;
- Start time and date;
- Start water depth;
- End latitude and longitude;
- End time and date;
- Wind speed;
- Wind direction;
- Wave height;
- Air temperature; and
- Vertical CTD profile, and continuous observations of bottom temperature while the gear is fishing (*see* Section 5.4).

5.6 Data Entry and Reporting

Data will be transcribed from hard copy datasheets into electronic worksheets. The data sheets will be reviewed for data entry errors prior to importing into a relational database. Quality control checks will be performed on database tables by running standardized, systematic queries to identify anomalous data values and input errors. Species names (common and scientific) are verified and tabulated for consistency. All data used in analysis will be exported from the relational database.

Annual reports containing catch data will be prepared after the conclusion of each year of sampling and shared with State and Federal resource agencies. One final report will also be produced synthesizing the findings of the pre- and post-construction evaluations.

5.7 Data Analysis

The BAG survey design will allow for characterization of pre-construction community structure of fish species associated with complex bottom habitats and will continue sampling after construction to allow for quantification of any changes in relative abundance associated with installation and operation of wind turbines in the SFWF site. The primary question to be asked is, what is the pattern of temporal change in relative abundance, relative to distance from a turbine foundation? The null hypothesis associated with this design is that relative abundance will remain the same over time and remain consistent with respect to the distance from a turbine (i.e., the coefficient describing the influence of distance from a turbine on catch is not different from zero). Several statistical models will be compared (e.g., GLM, GLMM, or GAM) with distance treated as a main effect (continuous variable), and the best fitting model for each species will be used to estimate the 90% CI on the before-after change in the distance coefficient. Further, information on depth and bottom temperature collected at sea may be considered as covariates in the model to evaluate their influence on CPUE. Habitat data collected during the benthic SPI/PV surveys (Section 7.0), from Orsted geophysical surveys, or at sea (using the sounder to broadly classify habitat) can also be considered as covariates in the model to evaluate the influence of habitat on CPUE. Graphical methods and descriptive statistics will be used to assess changes in CPUE over time, as a function of distance from the turbine foundations. These graphical techniques may help to elucidate the spatial scale at which relative abundance changes the most with distance from the turbine foundation. Data analysis will be performed in accordance with the BOEM fishery guidelines.

This study design assumes that each fish pot along a trawl will sample independently from the other pots on the trawl. However, given the desire to sample intensively at locations adjacent to the turbine foundations, the density of fish pots (and thus density of bait) will not be homogenous along the length of each trawl. Therefore, this assumption should be evaluated. Graphical comparisons of CPUE at each pot along a string, particularly during the pre-construction period (before the habitat associated with turbines and scour protection are introduced) will help to elucidate whether the density of pots along a string influences CPUE. In particular, given that the five pots that will be deployed closest to the turbine will only be spaced 10m apart, the CPUE in these five pots should be compared to the other pots along the string to determine the potential influence of fish pot density and spacing on catch rates.

Table 4. Summary of the planned analyses for the fish pot survey.

Design Overview	Design details	Metrics of Interest	Research Question	Post-Construction Statistical Methods
Impact only (no reference sites); pots at distances ranging from ~10m to ~900m from turbine; April - October (1x per month); 24 hour soak time	**Sampling frame** = single direction from turbines in SFW **Observational unit** = individual pot (turbines and string locations fixed throughout study). **Response variable** = annual mean CPUE per distance **Error variance** = among replicate pots at the same distance (turbines provide replication).	**Catch** of key species (black sea bass, scup, tautog)	What is the pattern of temporal change (B/A) in catch as a function of distance from turbine?	Fit the GLM (or GLMM or GAM) that best describes the data; estimate the 90% CI on the B/A contrast for the distance effect. Biological and physical covariates (from Benthic SPI/PV Survey) will be considered, along with other covariates (T, depth). Graphical assessment of changes (B/A) in catch over distance and time.
	Observational unit = individual fish/invertebrate **Response variable** = length **Error variance** = among individual fish/invertebrates	**Length frequency**	How does size structure change over time (B/A)? How does size structure compare between areas (C/I)?	1. descriptive (range, mean) 2. graphical and statistical comparison (between times and locations) of ECDFs using distributional comparison test (e.g., Kolmogorov-Smirnoff).
	Observational unit = individual fish **Response variable** = condition index **Error variance** = among individual fish	**Fish condition index** (i.e., deviations from log-length vs log-weight relationship) by species	What is the magnitude of change in fish condition over time (B/A), or between areas (C/I)?	Find the best fitting model to the condition values by species, and calculate 90% CI of the relevant contrasts.

Definitions:
BAG = before after gradient
90% CI = 90% confidence interval
ECDF = empirical cumulative distribution function

An adaptive sampling strategy is being proposed as part of this monitoring plan. Upon completion of sampling in 2021, and again following sampling in 2022, an evaluation will be conducted of the statistical power associated with this sampling design. This analysis will use an approach similar to what was performed for the ventless trap lobster survey (Appendix D) but made relevant to the study design and model used for this survey. Potential impacts on relative abundance from windfarm operation may include: an overall change in the mean CPUE over time, a step change in the mean at some distance from the turbine foundations during the operation period, or a gradual change in abundance expressed as a function of distance from the foundations (e.g., a slope in a regression equation). The variance (e.g., RSE) associated with the relative abundance estimates for black sea bass and scup will be calculated for the data from years 1 and 2. Using the observed variance estimates, power curves will be used to demonstrate how expected statistical power varies as a function of effect size (i.e., the magnitude of change) and sample size (i.e., number of turbines sampled). For this assessment of the potential impact on the relative abundance of black sea bass and scup, 90% confidence (two-tailed $\alpha = 0.10$) and at least 80% power ($\beta = 0.20$) will be used to ensure that the monitoring will have a probability of at least 80% of detecting a targeted effect size, if it is present.

The results of the power analysis may be used to modify the monitoring protocols in subsequent years. The decision to modify sampling will be made after evaluating several criteria including the amount of variability in the data, the statistical power associated with the study design to detect a targeted effect size, and the practical implications of modifying the monitoring protocols. For example, if the power analysis demonstrates that the proposed sampling will not achieve the desired level of statistical power, sampling intensity may need to be increased, which could be achieved throughout the remainder of the study by sampling additional turbines, by sampling the existing stations more often each month (e.g., two monthly sampling events, rather than one), or by increasing the duration of the post-construction monitoring.

6.0 Acoustic Telemetry

Passive acoustic telemetry can monitor animal presence and movements across a range of spatial and temporal scales. For instance, each acoustic receiver provides information on the fine-scale (tens to hundreds of meters) residence and movement of marine organisms. Acoustic receivers also offer continuous monitoring, allowing for behavior, movements, and residence to be investigated at a fine temporal scale (e.g., diel, tidal, etc.). By leveraging observations collected across individual receivers, and receiver arrays, telemetry can also monitor animal presence and movement over a broad spatial and temporal extent. Therefore, passive acoustic telemetry is an ideal technology to not only collect pre-construction data on species presence within WEAs, but also to monitor and evaluate short and long-term impacts of wind energy projects on species presence, distribution, and persistence.

The use of passive acoustic telemetry has grown dramatically over the past decade and continues to grow each year (Hussey et al. 2015). As a result of this rapid growth, hundreds to thousands of acoustic receivers are deployed each year in the northwest Atlantic from the Gulf of St Lawrence to the Gulf of Mexico, each of which is capable of detecting the thousands of active transmitters that are currently deployed on at least 40 species including, among many others, sturgeon, striped bass, sea turtles, sharks, bluefin tuna, and black sea bass.

In particular, acoustic telemetry has proven to be a valuable research tool to understand the seasonal movements, spawning behavior, and spawning site fidelity of Atlantic cod in the Gulf of Maine (e.g., Dean et al., 2014, Zemeckis et al., 2014; Zemeckis et al., 2019). Cod have been observed to spawn in the waters of southern New England, primarily between December and March, with evidence of spawning on Cox Ledge and also in the surrounding areas to the south and west of Cox Ledge (Dean et al., 2020; Cadrin et al., 2020; Langan et al., 2020; Inspire Environmental, 2020). In addition, the Atlantic Cod Stock Structure Working Group concluded that cod in southern New England likely comprise a unique biological stock, that is distinct from the adjacent Georges Bank and Gulf of Maine stocks (McBride et al., 2020). Therefore, monitoring for the impacts of offshore wind development for cod in SFWF has been recognized as a priority.

Inspire Environmental recently completed a rod and reel survey of cod in the SFWF project Area and nearby locations over two winters, to identify spawning aggregations and examine the spatial distribution of cod during the spawning season (Inspire Environmental, 2020). While the rod and reel study provided valuable information, inferences were generally limited by the low sample sizes (e.g., mean daily catch rates of <1 cod per angler) obtained using this method. Given our inability to conduct a trawl survey within SFWF, and the sample size limitations that would likely be associated with an additional rod and reel survey, SFW considered acoustic telemetry to be the most suitable tool to collect high-resolution information on the seasonal distribution of Atlantic cod in SFWF and surrounding areas.

6.1 Ongoing Telemetry Research

SFW will coordinate with, and provide contributions to, ongoing acoustic telemetry projects in and around the SFWF site. There is an ongoing BOEM-funded study that is using passive acoustic telemetry to monitor the seasonal distribution and spawning activity of Atlantic cod on and around Cox Ledge, including within the SFWF work area (Figure 7). This Project includes scientists from the Massachusetts Division of Marine Fisheries, the UMass Dartmouth School for Marine Science and Technology, Rutgers University, the Nature Conservancy, Woods Hole Oceanographic Institute, and the NEFSC. To date, approximately 40 adult cod have been tagged with Vemco V16-4H acoustic transmitters, and additional tagging trips are planned for the fall and winter of 2020 to deploy the remaining transmitters. All tagging trips have been conducted on local for-hire recreational fishing vessels.

The movements and residency patterns of tagged cod are being monitored using fixed-station passive acoustic receivers, as well as a receiver that is attached to an autonomous glider. Ten acoustic receivers were deployed from a commercial gillnet vessel in November 2019, and the receiver array will remain in the water until at least May 2021. The autonomous glider allows for tagged fish to be detected over a wider area than is possible using the fixed-station receivers. In addition, the glider also collects environmental data including temperature, dissolved oxygen, and turbidity. In addition to the acoustic receiver and environmental sensors, the glider is also equipped with a Passive Acoustic Monitoring device, which is used to record and document the vocalizations of whale species in the study area, and the glider data is available in near real-time on the web (http://dcs.whoi.edu/cox1219/cox1219_we16.shtml). The glider deployments were scheduled to coincide with the presumed peak spawning season for Atlantic cod in southern New England. The autonomous glider was deployed in December 2019 and remained in the water until March 20th, 2020. The glider will be deployed again during the next two winters (December 2020-March 2021, and December 2021-March 2022).

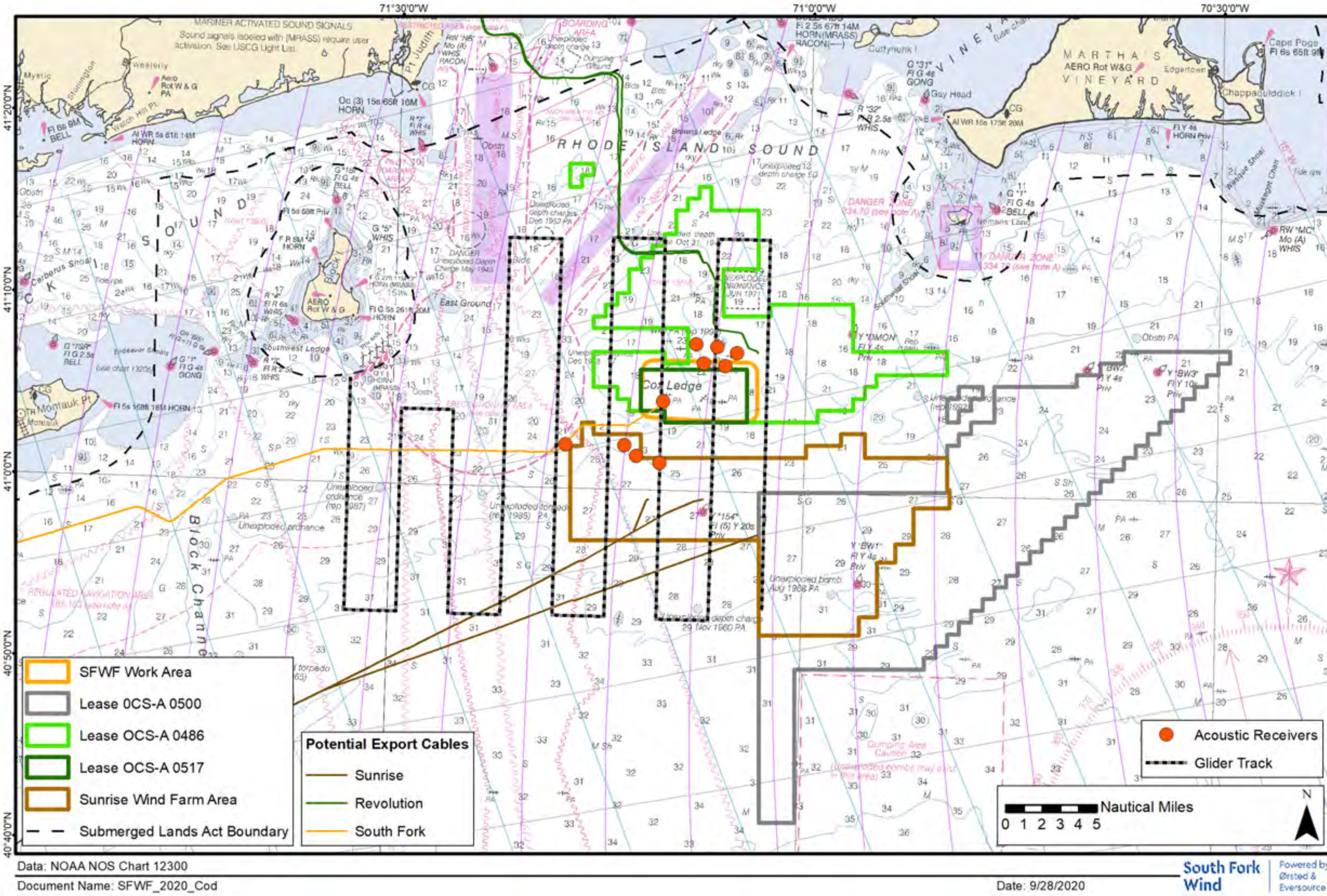

Figure 7. **Study site for the Atlantic cod acoustic telemetry study, including the location of the fixed-station acoustic receivers. The general track of the autonomous glider is also shown.**

A second acoustic telemetry study, which began in the summer of 2020 and is scheduled to continue through 2021, will examine the presence and persistence of Highly Migratory Species (HMS) at popular recreational fishing grounds in the southern New England WEAs. INSPIRE Environmental has partnered with the Anderson Cabot Center for Ocean Life (ACCOL) at the New England Aquarium to use passive acoustic telemetry to monitor the pre-construction presence and persistence of bluefin tuna, blue sharks, and shortfin Mako sharks in the southern New England WEAs. These species have been identified as three of the most commonly captured and targeted species by the offshore recreational community in southern New England (NOAA, 2019). Fifteen acoustic receivers were deployed in July 2020 at three popular recreational fishing sites within the WEAs identified through a previous recreational fishing survey carried out by the ACCOL (Kneebone and Capizzano, 2020). The receivers were deployed strategically in conjunction with the Atlantic cod receiver array, to maximize spatial coverage for both projects. Tagging trips have been conducted collaboratively with the recreational fishing community to target and tag 20 individuals of each of the three HMS species listed above.

As part of the pre-construction monitoring, SFW will provide financial support to strengthen these ongoing telemetry projects and contribute more broadly to regional telemetry research in the northwest Atlantic.

6.2 Acoustic Telemetry Methods

SFW will contribute to these ongoing acoustic telemetry efforts by providing additional funding to support these projects. SFW will provide support to the cod telemetry project team to purchase additional VR2W receivers that can be used to replace receivers that are lost during the course of the project, allowing the project team to maintain the scope of the receiver array. Further, SFW will also provide funds to the cod telemetry project to purchase the mooring equipment (e.g., line, buoys, anchors, etc.) that is needed to retrofit the receiver moorings that are currently being used. The purpose of retrofitting the receiver moorings is to minimize the loss of receivers, which will increase the spatial and temporal extent of coverage, help maintain data integrity, and allow the project to meet its' monitoring objectives. As part of the ECO-PAM project, an acoustic receiver has also been deployed near SFWF (41.06N 70.83W).

Additionally, SFW will provide financial support to the HMS telemetry project. This support will be used to purchase an additional two VR2-AR receivers, as well as additional replacement receivers needed to maintain the array if receivers are lost. These two receivers will be placed strategically within the SFWF site in November 2020 to enhance the spatial coverage of the receiver array prior to the cod spawning season. These receivers will remain in the water until March or April of 2022 in order to detect tagged HMS species, and to bolster the resolution of the telemetry array in SFWF during the cod spawning season. In addition, SFW will provide the funds needed to keep some (e.g., n = 3 to 5) of the HMS project's receivers deployed year-round, rather than having the receivers removed from the water each November, as was initially planned. The purpose of keeping the receivers in the water year-round is to increase the spatial scope of the receiver array during the winter months when cod spawning occurs on Cox Ledge and in the surrounding areas (Dean et al., 2020; Langan et al., 2020). Receivers will be rigged using standard procedures outlined by Vemco for benthic deployment (https://www.vemco.com/wp-content/uploads/2015/01/vr2ar-deploy-tips.pdf). Further, SFW will provide salary support for the PI's from the HMS telemetry study (Dr. Kneebone and Mr. Gervelis) to compensate them for their time associated with the year-round maintenance of the receiver array, and analysis of the detection data.

These financial investments will bolster both ongoing telemetry projects and increase the spatial and temporal resolution of information that is collected, particularly during the cod spawning season (December through March). The high-resolution data collected using acoustic telemetry will provide a valuable supplement to the monitoring plan and improve our understanding of cod habitat use within the SFWF area, particularly during the spawning season, which is a time period that is not well sampled by the regional fishery independent surveys, and a time period for which there is limited fishery-dependent data collected for the recreational fishery.

6.3 Data Analysis and Data Sharing

The resulting detection data downloaded from acoustic receivers will be analyzed with the overall goal of establishing pre-construction information on species presence and persistence in SFWF. Short- and long-term presence, site fidelity (i.e., residency/persistence), fine- and broad-scale movement patterns, and inter-annual presence at SFWF (i.e., whether individuals return to the receiver array each year) will be examined. Any detection data obtained through our participation in regional telemetry data sharing networks will be incorporated into this analysis, particularly to examine the distribution and movements of species beyond the confines of SFWF. Deliverables include detailed detection history plots for each tagged individual that depict all detections logged for an animal over the course of a year. Summary tables and figures will be generated that describe: the number of times each fish was detected by receivers in SFWF, the detection history for each fish, the total number of receivers it was detected on, movements, and monthly patterns in presence and persistence. In addition to the local-scale acoustic monitoring achieved by the proposed receiver array, broad-scale movement data will be accomplished through participation in regional telemetry data sharing programs, in an attempt to obtain detection data from our tagged animals wherever else they are detected in the greater Atlantic region.

All detection data recorded by the acoustic receivers in this Project will be distributed to researchers through participation in regional telemetry networks such as the Ocean Tracking Network or the Mid-Atlantic Acoustic Telemetry Network (MATOS). We will compile any detection data that we collect for transmitters that are not deployed as part of the proposed Project and disseminate that information to the tag owners (it is the policy of regional data sharing programs that the ‘owner’ of the data is the entity that purchased and deployed the transmitter, not the entity that detected it on their receiver). We will also approach each transmitter’s owner to request the inclusion of their data (i.e., metadata on the species detected, number of detections, amount of time the animal was detected in our receiver array, etc.) in any analyses performed. Ultimately, participation in these large data sharing networks will increase both the spatial and temporal extent of monitoring for species tagged as part of this research effort and permit the collection of data on the presence and persistence of other marine species tagged with acoustic transmitters (e.g., Atlantic sturgeon, striped bass, white sharks) in and around SFWF at no additional cost.

7.0 Benthic Survey – Sediment Profile Imaging – Plan View and Video

Installation and operation of OSW projects can disturb existing benthic habitats and introduce new habitats, with the level of impact and recovery from disturbance observed to vary depending on existing habitats at the site (HDR 2017, Wilhelmsson and Malm 2008). Habitat alteration during construction may include boulder relocation; mechanical or hydraulic disturbance of sediments; and placement of scour protection layers (Dannheim et al. 2020). After installation, the WTG structure introduces supratidal to subtidal hard habitat to the project site: hard vertical substrates and, depending on the type of foundation and the degree of scour protection used, a range of horizontal habitat complexity (Langhamer, 2012).

Over time (3-6 years), the introduction of the hard substrata (novel WTG surfaces, scour protection layers, cable protection layers, and natural boulders) can lead to extensive biological growth over the unoccupied surfaces with a complex pattern analogous to shoreline intertidal to subtidal zonation (artificial reef effect, Petersen and Malm 2006, Ruebens et al. 2013). This biological growth has led to dense accumulations of filter feeding mussels in the intertidal (i.e., on the turbines at the water surface) followed by amphipods, tunicates, sponges and sea anemones in the subtidal in Europe (De Mesel et al., 2015) and at the Block Island Wind Farm (BIWF, HDR 2020). The high-volume filter feeders (mussels) capture phytoplankton and marine snow and discharge large volumes of pseudofeces (organic mineral aggregates with high carbon content) that settle to the seafloor (Lefaible et al., 2019). Three to six years after installation, seafloor locations <50 m from the foundation showed evidence of finer sediments and increased organic matter compared to locations 350-500 m away (Lefaible et al., 2019).

The epifaunal species colonizing the new hard bottom substrata are also of direct interest. In New England waters, non-native species have been identified as potential competitors for space with native species and commercial harvests of shellfish (Lengyel et al. 2009, Valentine et al. 2007).There is evidence at BIWF that the introduction of mussels led to mussel colonization of adjacent subtidal hard and soft bottom habitats (HDR 2020, Wilber et al. 2020). At BIWF and European projects, native and non-native species (e.g., at BIWF colonial tunicates, *Didemnum vexillum*) have been observed to colonize new hard bottom substrate within six months to two years (HDR 2020, Guarinello and Carey, 2020). *D. vexillum* has been observed within the SFWF project area, but there is limited information available to understand the current abundance and distribution of *D. vexillum* on hard bottom habitats (Deepwater Wind South Fork 2020).

These observations from existing OSW projects lead to two prevailing hypotheses of likely effects:

1. Enrichment of seafloor conditions from WTG artificial reef effect within 3-6 years (1-100 m from WTG) leading to fining and higher organic content of soft bottom habitats.

2. Introduction of attached organisms (both native and non-native) to existing natural hard bottom habitats with potential for rapid colonization of relocated boulders.

The consequences of these predicted effects are to potentially affect the function of soft and hard bottom habitats to provide food resources, refuge, and spawning habitat for commercial fish and shellfish species (Reubens et al., 2014, Krone et al. 2017).

For this operational monitoring plan, monitoring of soft bottom habitats will focus on measuring physical changes and indicators of benthic function (bioturbation and utilization of organic deposits, Simone and Grant 2020) as a proxy for measuring changes in the community composition. Monitoring of hard bottom habitats will focus on measuring changes in macrofaunal attached communities (native vs. non-native species groups), percent cover, and physical characteristics (rugosity, boulder density) as a proxy for measuring changes in the complex food web. The schedule for monitoring these two benthic habitats is outlined in Table X and discussed in more detail in the following sections. These indicators of the function of soft and hard bottom habitats provide quantitative data, can support rapid data collection and analysis, and lead to effective management actions (mitigation). They are not designed to answer research questions.

Table 5. Schedule of soft bottom and hard bottom benthic surveys

Survey	Soft bottom WTG	Soft bottom SFEC	Hard bottom Turbine surface	Hard bottom IAC
Season	Late summer	Late summer	Late summer	Late summer
Pre seabed preparation	SPI/PV – within 6 months prior		SPI/PV – within 6 months prior	MBES, SSS, ROV – within 12 months (timed to avoid gear conflicts)
Post seabed preparation				MBES, SSS, ROV - within 1 month
Post construction Year 0	SPI/PV – earliest Late summer after construction	SPI/PV – earliest Late summer after construction	ROV – earliest Late summer after construction	ROV – earliest Late summer after construction
Post construction Year 1	SPI/PV	SPI/PV	ROV	ROV
Post construction Year 2			ROV	ROV
Post construction Year 3	SPI/PV	SPI/PV	TBD	TBD
Post construction Year 4				
Post construction Year 5	SPI/PV	SPI/PV		
Post construction Year 6	TBD	TBD		

TBD is adaptive monitoring if evidence that location is still changing from previous sampling period

7.1 Soft Bottom Monitoring

Soft bottom monitoring will be conducted within the project area and along the SFEC with a Sediment Profile and Plan View Imaging (SPI/PV) system. SPI/PV provides an integrated, multi-dimensional view of the benthic and geological condition of seafloor sediments and will support characterization of the function of the benthic habitat and physical changes that result from construction and operation of SFWF.

A SPI/PV survey will characterize the geological (sediment size and type) and benthic (animal habitat) characteristics of the soft-sediment areas with consideration of potential effects from wind farm operation. A PV survey will characterize surficial geological and biotic (epifaunal) features of hard-bottom areas within the sample area but will not replace a dedicated hard bottom survey (Section 7.2).

Existing benthic data from the SFWF area and the SFEC were primarily collected in late summer or fall (August to November), when biomass and diversity of benthic organisms is greatest (Deepwater Wind South Fork 2020, HDR 2017, 2019, NYSERDA, 2017, Stokesbury, 2013, 2014; LaFrance 2010, 2014). In contrast to fish communities and harvestable benthic species, benthic habitats in the NE Atlantic are generally stable in the absence of physical disturbance or organic enrichment (Theroux and Wigley 1998, Reid et al. 1991, Steimle 1982, HDR 2019). A BAG survey design will be used to determine the spatial scale of potential impacts on benthic habitats and biological communities within the proposed SFWF site and along the SFEC. A single benthic survey conducted in late summer (August to October) six months prior to the start of construction activity will be used to represent benthic habitats prior to potential disturbance. Subsequent surveys will be conducted in the same seasonal time frame at intervals of 1 year, 3 years and 5 years after completion of construction (Table X).

7.1.1 Survey Design/Procedures

The SPI/PV surveys will be conducted at SFWF using fixed stations to assess the spatial scale and extent of wind farm effects on benthic habitat over time. The surveys will be conducted from research vessel(s) with scientists onboard to collect images utilizing a SPI/PV camera system. This system was utilized exclusively for ground-truth imagery of high-resolution geophysical surveys to support benthic habitat mapping within SFWF for EFH characterization and was very effective (Deepwater Wind South Fork 2020). Collecting seafloor imagery does not require disturbance of the seafloor or collection of physical samples. For-hire vessels will be selected based on criteria such as survey suitability, experience, safety record, knowledge of the area, and cost. All survey activities will be conducted with strict adherence to Orsted health and safety protocols to reduce the potential for environmental damage or injury.

Replicate SPI/PV images will be collected at each station, with the number of replicates specific to survey type (*see* Sections 7.1.2 and 7.1.3). Results from the targeted number of replicates with suitable quality images will be aggregated to provide a summary value for each metric by station.

7.1.2 Sampling Stations – Turbine Foundations

The objectives for the soft bottom benthic survey are to measure changes over time in the benthic habitat and physical structure of sediments at varying spatial scales relative to turbine foundations. To accomplish the goals of this survey, data will be collected before and after installation and operation of SFWF using a BAG survey design with statistical evaluation of the spatial and temporal changes in the benthic habitat (Underwood, 1994; Methratta, 2020). The selection of a BAG design is based on an understanding of the complexities of habitat distribution at South Fork and an analysis of benthic data results from European wind farms and the RODEO study at BIWF (HDR 2017, 2019, 2020, Coates et al., 2014; Dannheim et al., 2019; Degraer et al., 2018; LeFaible et al., 2019; Lindeboom et al., 2011). SPI/PV surveys have been conducted within the SFWF and along the SFEC to provide detailed assessment of benthic habitat for EFH consultation (Deepwater Wind South Fork 2020). This information on habitat distribution at SFWF was used to design the surveys specified in this and the following section.

The proposed BAG survey design eliminates the need for a Reference Area, as this design is focused on sampling along a spatial gradient within the area of interest rather than using a control location that may not be truly representative of the conditions within the area of interest (Methratta, 2020). This design also allows for the examination of spatial variation within the wind farm and does not assume homogeneity across sampling stations (Methratta, 2020).

Habitat types mapped within SFWF include glacial moraine, coarse sediment, sand and muddy sand, and a discrete area of mud and sandy mud at the northern boundary (Figure 8). The soft bottom benthic survey will focus only on the mobile sediment classes (sand, muddy sand), while hard bottom areas (glacial moraine with boulders and cobbles) will be addressed in a separate survey (Section 7.2). Turbine locations dominated by glacial moraine within 200m in one or both of the targeted NE-SW directions (i.e., WTG#1, #4, #5, #8 #9, #10, #16A, #17A) will be excluded from the soft sediment sampling frames. In addition, sampling transects will be specifically placed to avoid adjacency to the inter-array cable route (IAC); monitoring for the effects of a buried power cable is the focus of a separate survey (Section 7.1.3).

From the turbines with appropriate soft bottom habitat, any turbines that were randomly selected for the fish pot survey (Section 5.2) will be included in this survey with additional turbine locations randomly selected to achieve a total sample size of eight turbine locations. The selected turbine locations and transect positions will remain fixed for the duration of the survey.

This survey was designed to sample at increasing distances from turbine locations, based on the hypothesis that colonization of epifaunal growth on the turbines will result in changes to the surrounding soft bottom benthic habitat. Enrichment of soft bottom habitats from the artificial reef effect is expected to be most pronounced down current and weaker up current. A current meter record collected for the RI Ocean Special Area Management Plan (Ocean SAMP) indicated that monthly mean currents near SFWF are relatively strong from March through October and generally to the west-southwest (Ullman and Codiga, 2010). Two belt transects (25m wide) of SPI/PV stations will be established to the northeast (up current) and southwest (down current) of the eight selected turbine locations to avoid IAC locations (cable effects addressed in Section 7.4). Pre-construction transects will begin at the center point of the planned foundation with two stations at equal intervals up to the maximum planned extent of the scour protection area (34 m) and then at intervals of 0-10m, 15-25m, 40-50m, 90-100m, 190-200m, and 900m extending outward from the edge of the scour protection area (i.e., a single station at each of eight distance intervals in two directions from each turbine sampled; Figure 9). Post-construction transects will repeat this design at the same turbines and the same sampling intervals. These distances were chosen based on recent research indicating that effects of turbines on the benthic environment occur on a local scale (e.g., Lindeboom et al., 2011; Coates et al., 2014; Degraer et al., 2018; HDR 2019). In the Belgian part of the North Sea, gradient sampling of benthic habitat within wind farms was conducted at close stations and far stations that were up to 500 m away from the turbine foundations (LeFaible et al., 2019). However, recent unpublished data from Belgium indicates some level of enrichment has been recorded between 200-250 m from the turbines after eight years (personal comm. S. Degraer, 4/29/2020). The turbines are proposed to be built in a regular grid pattern, with 1nm spacing between adjacent turbines. The maximum sampling distance (900m) was selected to cover half of the distance between adjacent turbines. These stations characterize habitat changes over time within the wind farm in general, representing potential cumulative effects of the wind farm in aggregate but are not associated with the enrichment hypothesis adjacent to the turbines. Turbines that are part of the fish pot survey will be additionally sampled at distance intervals that coincide with the locations of the fish pots; care will be taken to avoid interaction between the two surveys.

Eight replicate SPI/PV image pairs will be collected at each station; results from six replicate pairs with suitable quality images will be aggregated to provide a summary value for each metric by station.

To provide context for assessment of the potential enrichment effect, the vertical surfaces of all turbines selected for sampling will be surveyed using ROV (*see* Section 7.3.2). These visual surveys of the foundation (around the circumference and at different elevations from sediment surface to water surface) will provide information about cover of epifauna/epiflora on the turbine itself (the presumed source of benthic enrichment) and identification to the lowest practicable taxa without direct sampling of the turbine surface. This information will be considered as explanatory variables for the magnitude and range of benthic enrichment observed in the soft bottom habitat surrounding the turbines.

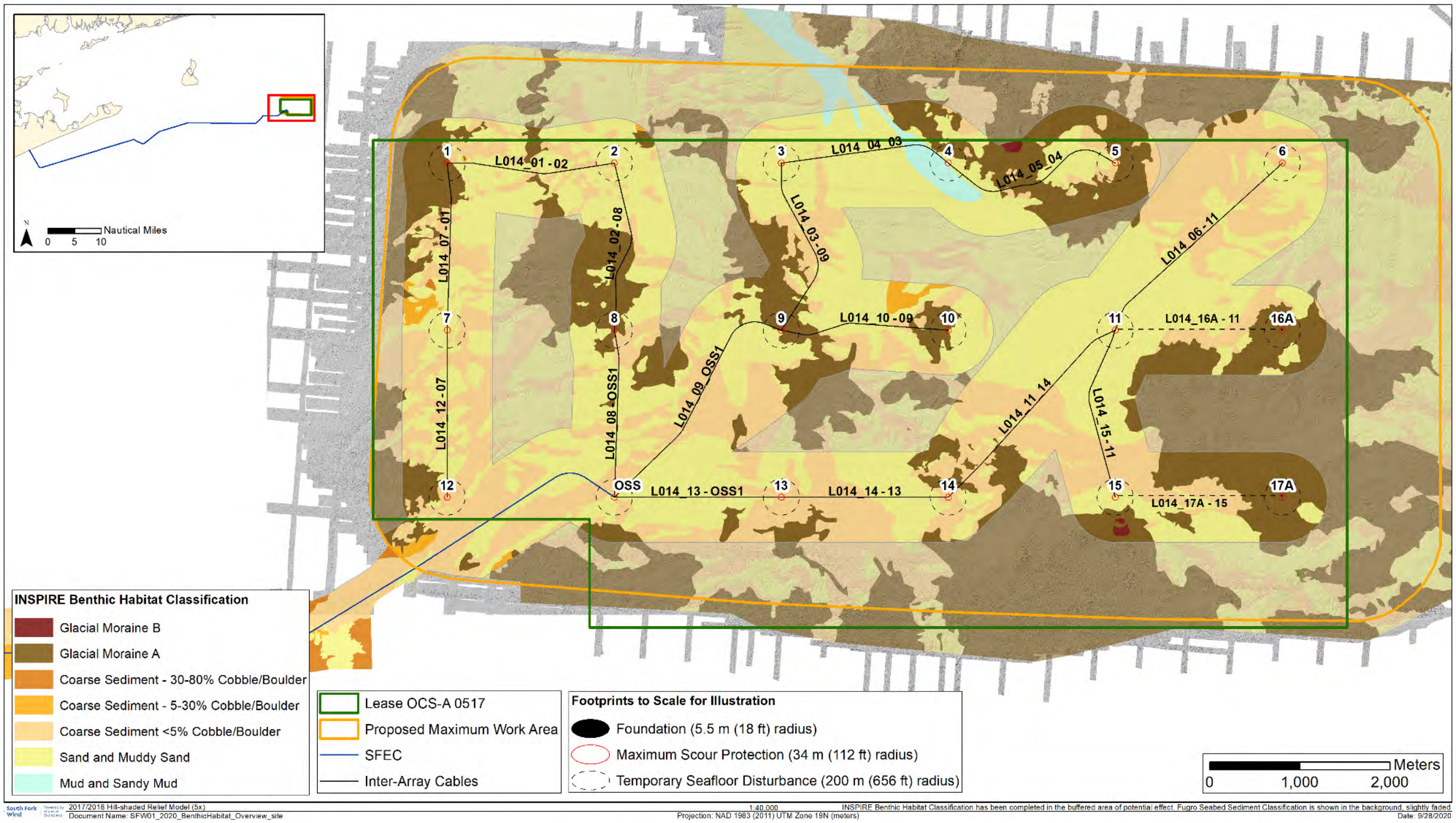

Figure 8. Benthic habitat map around planned turbine and cable installations. For softbottom benthic survey, eight turbine foundations will be selected from this set to avoid boulder areas (glacial moraine), with consideration and coordination with fish pot survey planning.

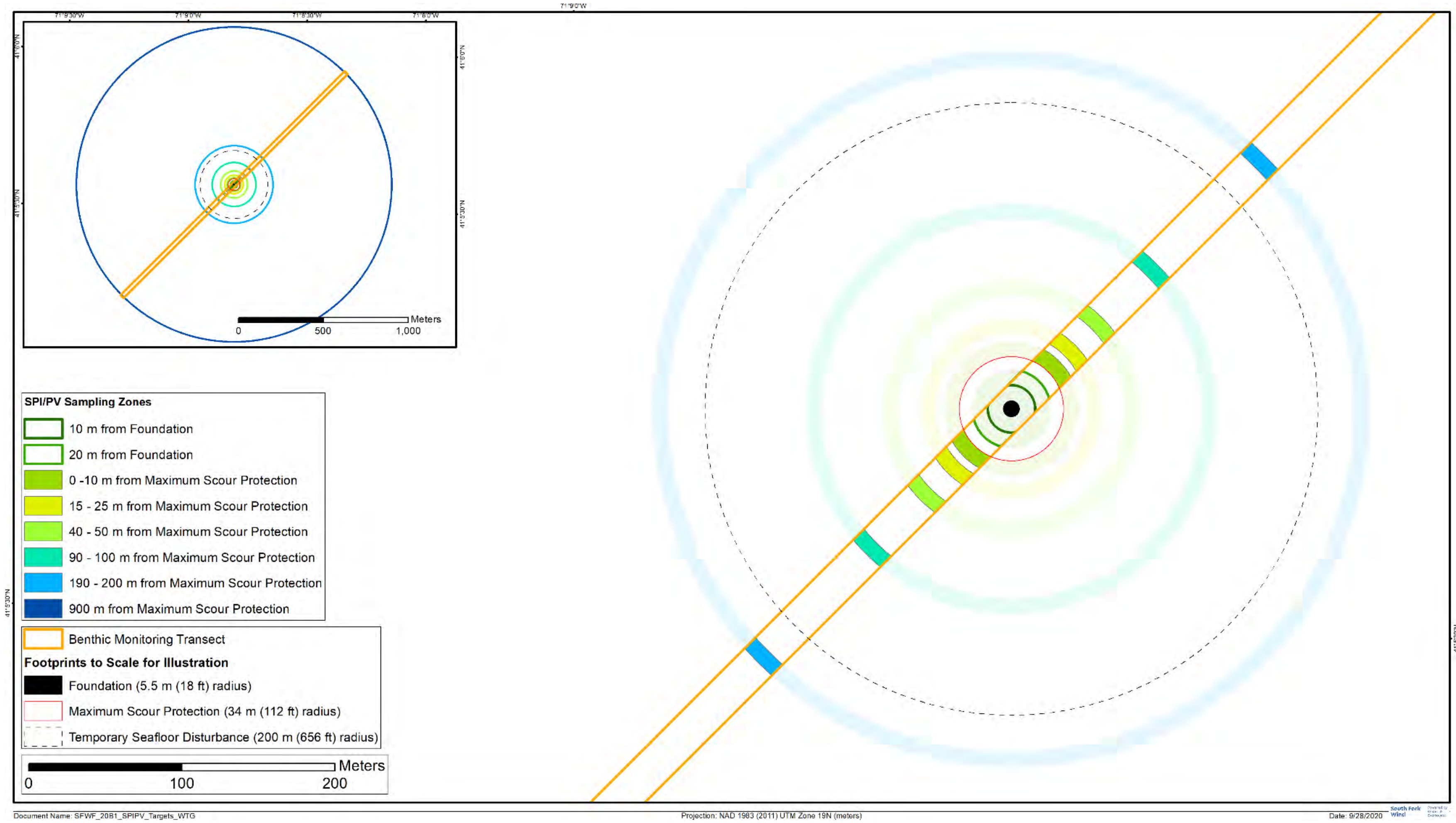

Figure 9. **Proposed soft bottom benthic survey sampling distances.**

7.1.3 Sampling Stations – South Fork Export Cable

The SFEC corridor includes a mix of soft bottom habitats ranging from coarse sand to sandy mud (Deepwater Wind South Fork 2020). The export cable transits areas with active commercial fishing with mobile gear including scallop dredging and trawling for groundfish and squid (Deepwater Wind South Fork 2020). The soft bottom survey sample design is focused on representative sections of the SFEC within areas with historically high fishing activity and areas with lower fishing activity.

Areas of coarse sand with > 30% cobbles or boulders are limited to the first 12 km of the cable route from the SFWF project site and a one km area near the NYS boundary (Figure 10). The effect of boulder relocation will be addressed in the hard bottom survey conducted within SFWF project area (Section 7.2).

The objectives of the soft bottom benthic survey at the SFEC are to examine the effects of installation and operation of an export cable on the benthic habitat using a BAG design (Ellis and Schneider, 1997). Any effects of installation and operation of the cable are expected to be roughly equivalent along the length of the cable. Some effects of installation may be altered by dredging or trawling activities as well as bottom sediment transport from tides and waves. The sampling design is intended to estimate effects along a spatial gradient away from the cable and will not estimate mean changes along the entire SFEC route. To accomplish the goals of this survey, data will be collected before construction and after operation of the SFEC at selected locations, using a BAG design similar to that proposed for the turbine foundations (Section 7.1.2). A 25m wide belt transect will be laid perpendicular to the cable route at six locations along the SFEC (Figure 9). A reconnaissance survey will be conducted prior to the first survey to define transect locations within sand habitats where there is a high expectation of sufficient fine sediment to support a robust benthic community with a measurable response to key variables of benthic health and sediment effects (aRPD, Successional Stage, grain size, sediment layering; *see* Section 7.5.1).

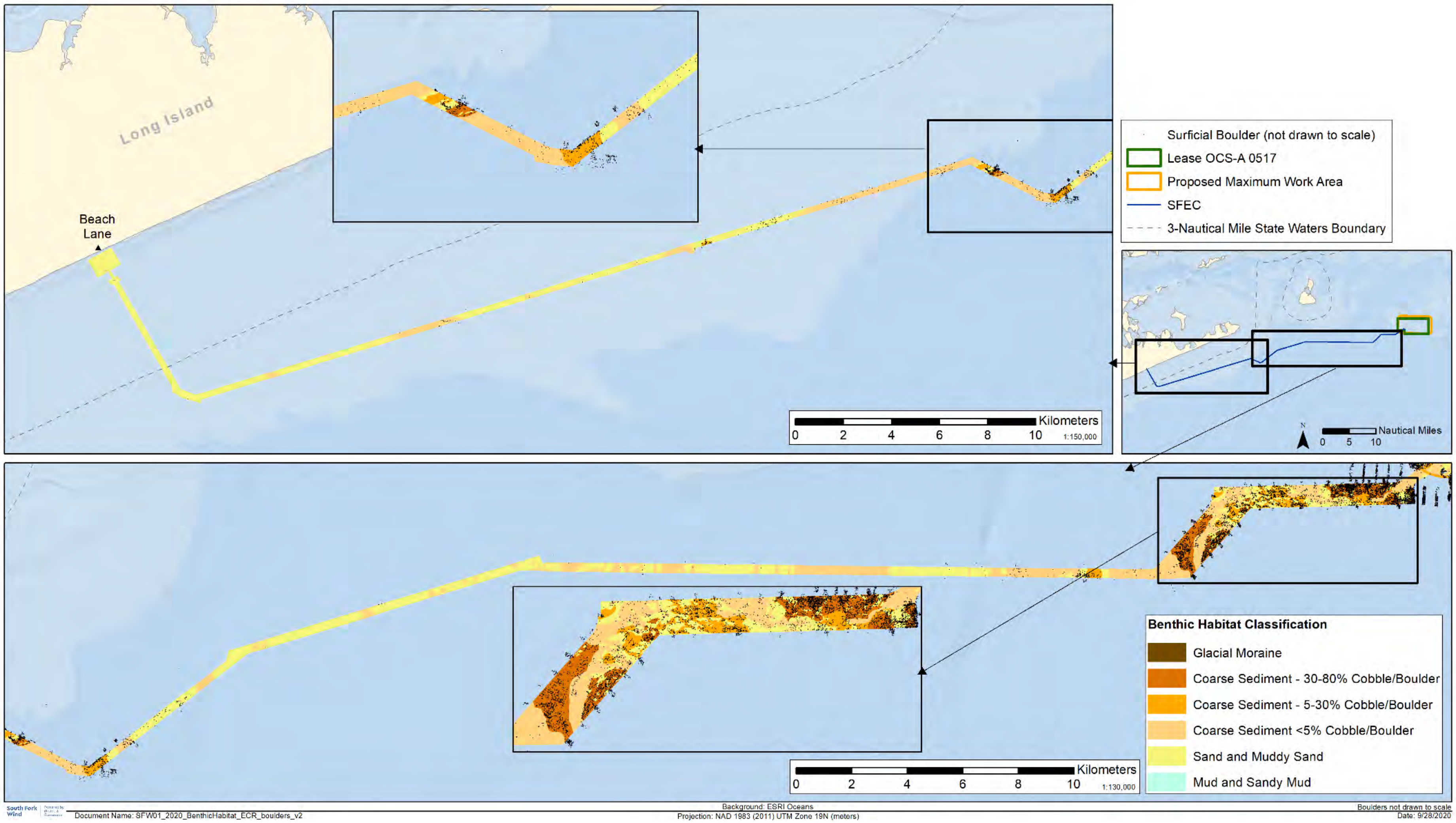

Figure 10. Distribution of benthic habitats along the SFEC with black dots indicating locations of surficial boulders > 0.5 m.

Three of the sampling locations will be distributed in an area where VTR data (2015-2016 or the most recent available) indicated an increased density of fishing activity, and the other three sampling locations will be distributed in similar habitat in areas with lower density of bottom contact mobile gear fishing activity. The process of cable installation will fluidize the sediments within an approximately ten meter wide band around the cable, altering the characteristics of the surface sediments down to two meters. Within the two areas (mobile gear fishing activity present or absent), sampling locations along the cable will be approximately one km apart. At each sampling location, SPI/PV images will be collected at intervals of 0-5, 10-15, 20-25, 30-40, 50-60, 90-100, 190-200, and 1000 meters on either side of the cable. The two sides of the cable are considered separate transects, for a total of six belt transects per area. The selected sampling locations and sampling intervals relative to the cable will remain fixed for the duration of the survey (Figure 11, Table 6). In previous SPI surveys of the SFEC (Deepwater Wind South Fork 2020), variability of habitat characteristics (i.e., aRPD, successional stage) was low among replicate SPI images, so fewer replicates are needed than for the survey at the turbine foundations were variability is expected to be higher. Four replicate SPI/PV images will be collected at each station; results from three replicates with suitable quality images will be aggregated to provide a summary value for each metric by station. An additional benthic survey of the SFEC will be conducted within NYS waters, which is presented in a separate monitoring plan (INSPIRE 2020).

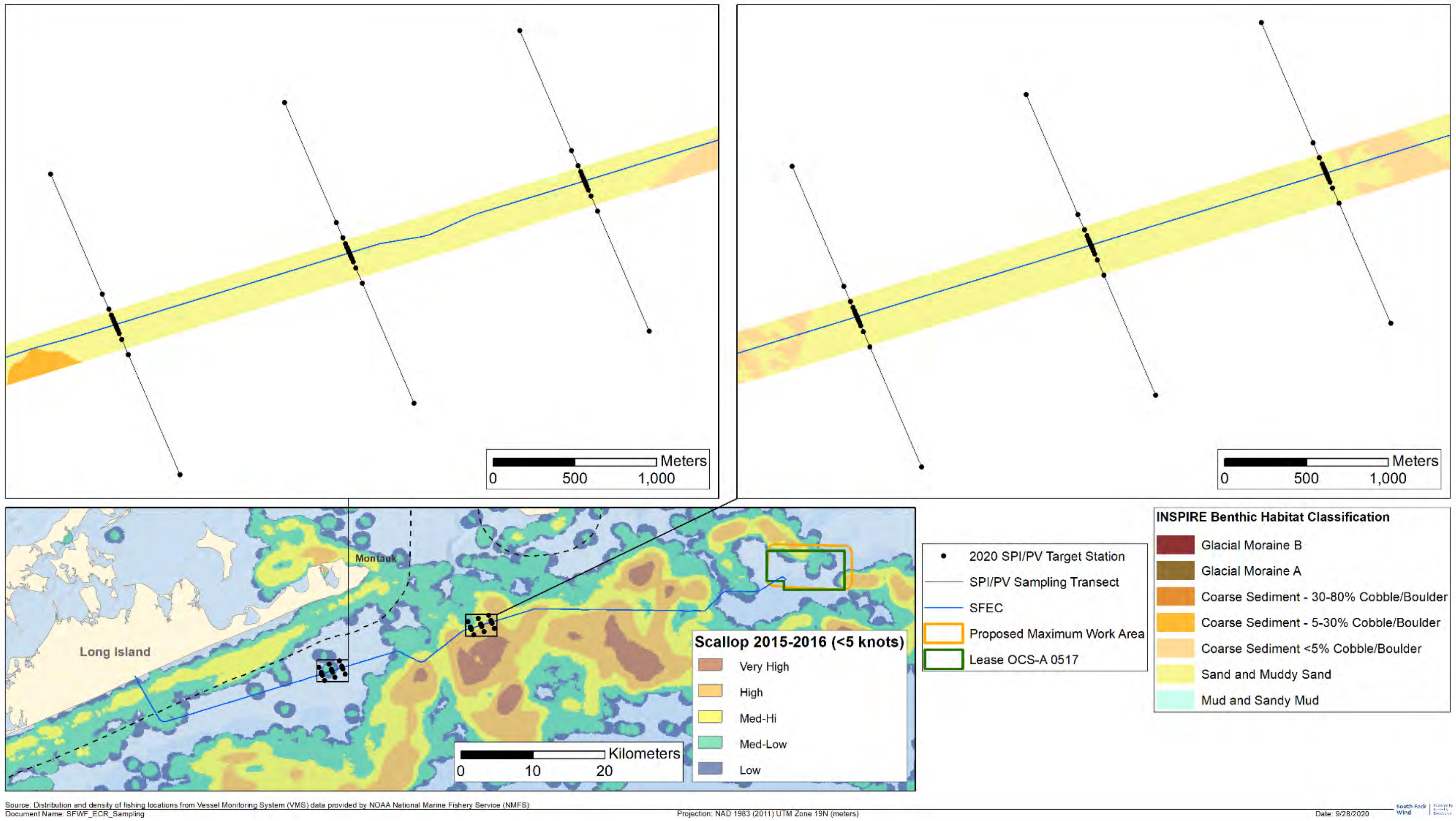

Figure 11. **Proposed soft bottom benthic survey sampling design along the SFEC with black dots indicating SPI/PV stations situated along transect perpendicular to the SFEC.**

7.2 Hard Bottom Monitoring

An acoustic and ROV video survey is planned to monitor hard bottom substrata within subareas of the SFWF project area. The SFWF benthic habitat includes areas with scattered boulders and cobbles on sandy substrata (Glacial Moraine A, Figure 6). Preparation of the seafloor for installation of the WTGs and IAC is expected to create clusters of natural hard bottom habitat subject to recolonization as well as discrete areas with increased rugosity and boulder density which can provide structural complexity and refuge for finfish and shellfish. Utilizing existing information about hard bottom habitat in areas expected to experience disturbance within the SFWF project area, two areas will be targeted for this survey: the IAC route south of WTG1 and IAC route north of WTG8 (Figures 12 and 13).

The primary objective for the hard bottom survey is to measure changes over time in the nature and extent of macrobiotic cover of hard bottom (i.e., percent cover and relative abundance of native vs. non-native organisms), contrasting undisturbed boulder areas with boulder areas disturbed by seafloor preparation activities for cable installation. The secondary objective is to characterize changes to the physical attributes of habitats in areas disturbed by seabed preparation for installation/construction: rugosity, boulder height, boulder density in relation to structural complexity and potential refuge for finfish and decapods.

Multibeam Echosounder (MBES) and side-scan sonar (SSS) surveys will be used to map hard bottom habitat within 12 months before (timed to avoid conflict with other surveying activities in the project area) and within one month after construction/installation is complete. From these detailed before-after acoustic maps, areas with modified boulder density (boulders > 1m in diameter) can be identified to form the sampling frames for the ROV video and imaging survey, as well as to characterize overall changes to the physical habitat attributes within the areas surveyed.

An ROV survey of boulders will be used to characterize macrobiotic cover of native vs. non-native species in the disturbed and undisturbed areas. A systematic random sample of boulders will occur within the sampling frames of disturbed/undisturbed areas approximately one month after seabed preparation (i.e. boulder relocation) has been completed, and again at six, 12, and 24 months (Table 5, based on observations at BIWF, Guarinello and Carey 2020). This design is based on an understanding of macrobiotic colonization of recently disturbed hard bottom habitat (Guarinello and Carey, 2020; De Mesel et al., 2015, Coolen et al., 2018), and detailed information of the distribution of hard bottom benthic habitat within the SFWF project area (Deepwater Wind South Fork 2020).

7.2.1 Survey Design/Procedures

Within the targeted areas (IAC routes south of WTG1 and north of WTG8), acoustic surveys will provide detailed maps of the seafloor and identify areas where boulders were undisturbed; and areas where boulders were relocated directly adjacent to the prepared IAC route (representing disturbed hard bottom; Figures 10 and 11). A single sampling frame will be identified within each of the disturbed and undisturbed areas for the two WTGs, placed to align with the presence of boulders based on the acoustic survey conducted immediately following seabed preparation for the cable installation. This type of non-probability (opportunistic) sampling will indicate macrobiotic cover within these areas but does not allow inference to the windfarm in general. A total of 20 random boulders from each sampling frame will be sampled using a systematic design.

Within one month after WTGs have been installed, an ROV will be used to collect reference images of the underwater surface of the turbine foundation to determine percent cover of macrofauna and microflora, native and non-native organisms and distribution of key suspension feeding organisms that could contribute to benthic enrichment (mussels, tube-building amphipods, etc.). ROV description and video collection methods are in Section 7.3.2.

The acoustic (SSS and MBES) and ROV surveys will be conducted from a research vessel with scientists onboard to collect acoustic data and images. The acoustic surveys of the two targeted areas will be collected in a single day and processed the following day; the ROV survey will be conducted immediately after processing of the acoustic data. Collecting seafloor imagery does not require disturbance of the seafloor or collection of physical samples. For-hire research vessels will be selected based on criteria such as survey suitability, experience, safety record, knowledge of the area, and cost. All survey activities will be conducted with strict adherence to Orsted health and safety protocols to reduce the potential for environmental damage or injury.

7.2.2 Sampling Stations

The primary objective for the hard bottom survey is to measure changes over time in the nature and extent of macrobiotic cover of hard bottom (i.e., percent cover and relative abundance of native vs. non-native organisms), in disturbed and undisturbed areas. A secondary objective is to characterize overall changes to physical hard bottom habitat as a result of seabed preparation for cable installation. Acoustic methods (SSS and MBES) will be used to map the distribution of hard bottom habitat before and within 1 month after seabed preparation for the cable installation. From these detailed before-after acoustic maps, areas with modified boulder density (boulders > 1m in diameter) can be identified to form the sampling frame for the ROV survey. The sampling will be conducted at regular distance intervals within a single sampling frame (5m wide and 200m or more in length) within each area (1 each in disturbed/undisturbed areas at WTG1 and WTG8, for a total of four frames), placed to capture sufficient density of boulders to sample. The ROV will progress along the centerline of each frame sampling boulders at 10m intervals until 20 samples have been obtained. Boulders may not be present at every planned interval, so sampling will progress as follows: the ROV will search within the 5m width of the sampling area in order to find a boulder to sample; the closest boulder to the target interval will be sampled, and the 10m interval will be reset. At each boulder, a photo image of a minimum 0.5m x 0.5m field of view of the visible portions of the boulder will be collected from which cover and native/non-native species will be identified. Data collected to inform the habitat characteristics for each sampling frame will include: rugosity and percent hard bottom to soft bottom from the acoustic surveys; height of boulder and percent cover of native and non-native species from the ROV survey.

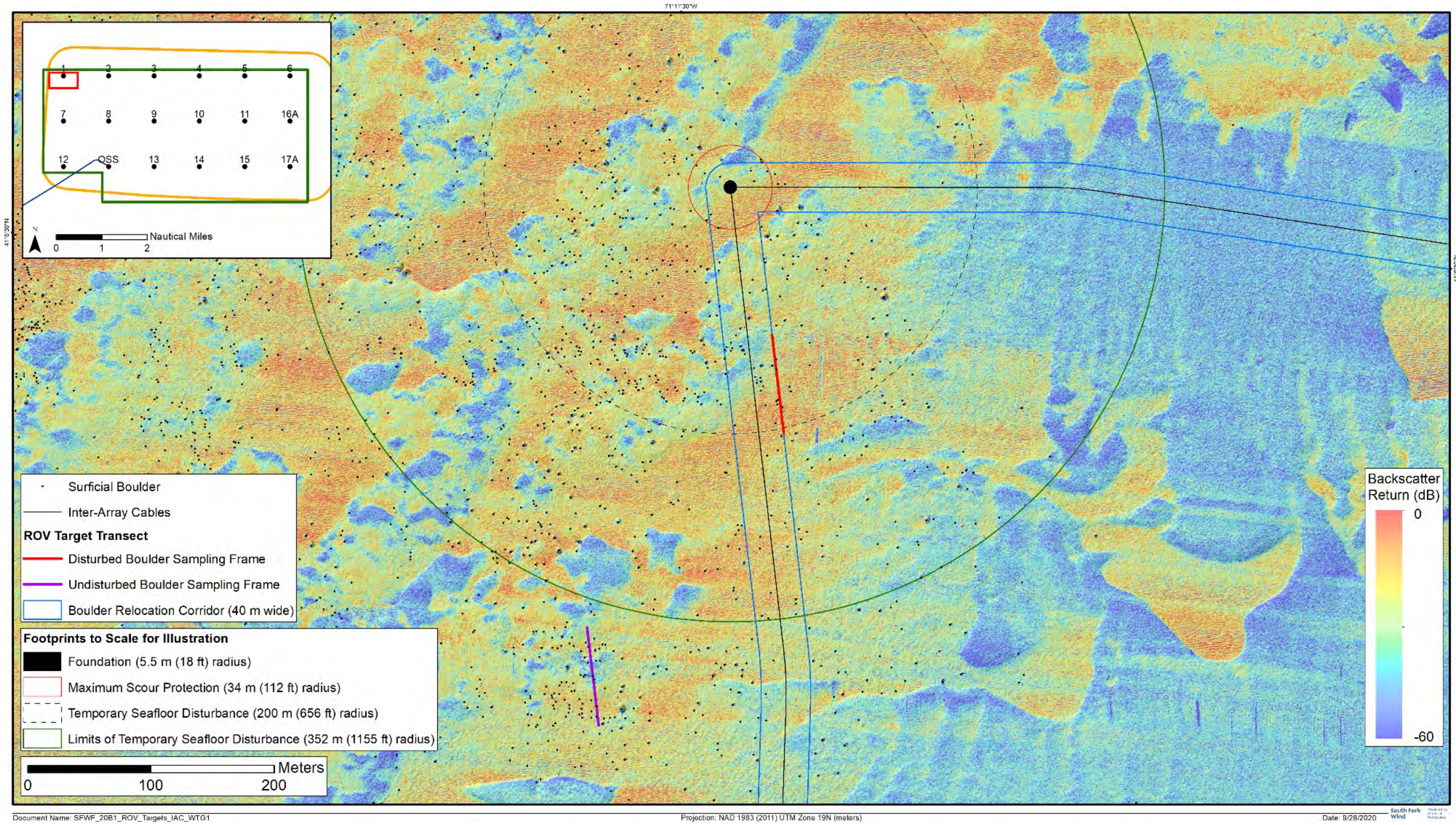

Figure 12. **Proposed hard bottom benthic survey sampling design along the IAC at WTG1.**

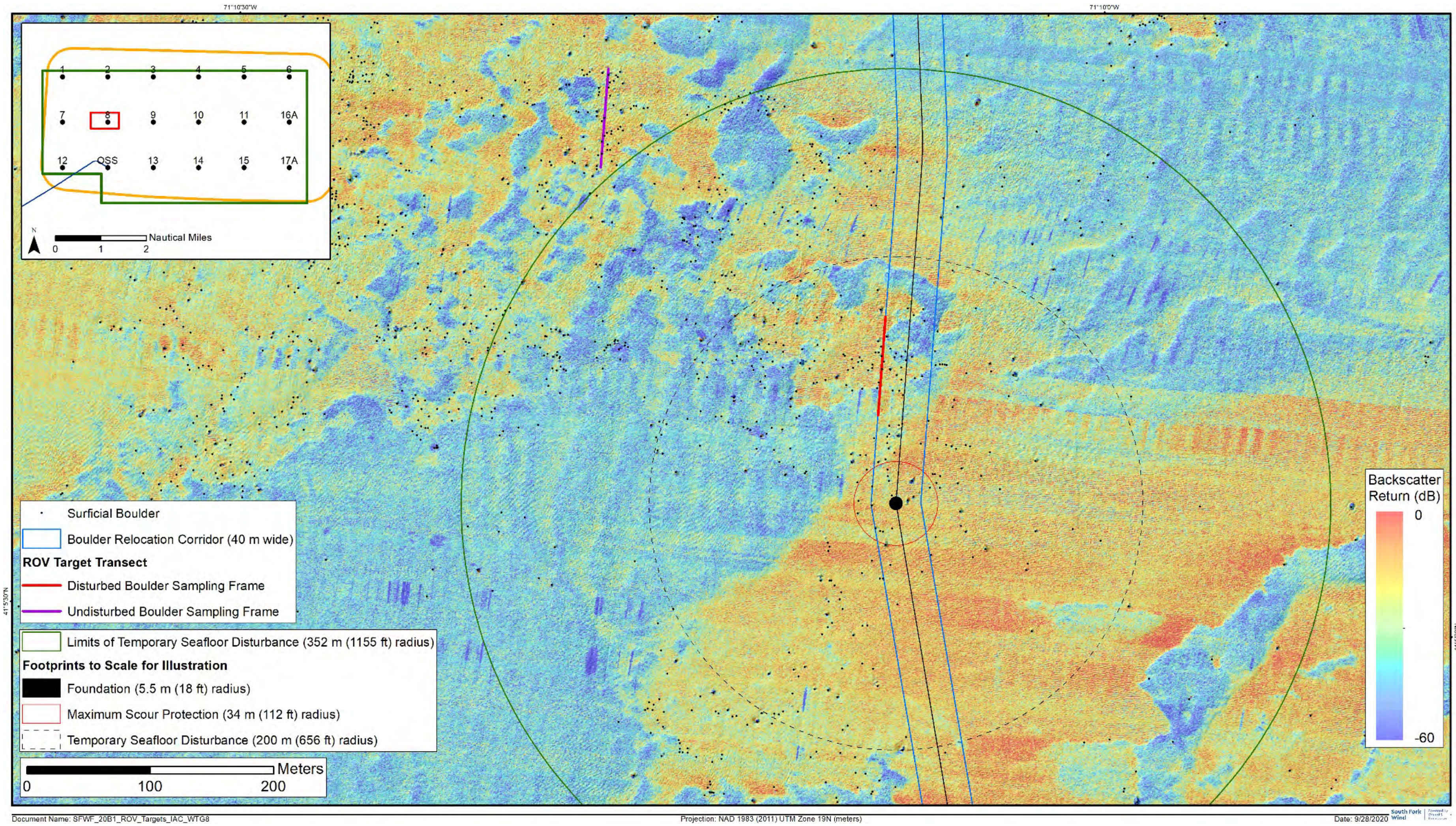

Figure 13. **Proposed hard bottom benthic survey sampling design along the IAC at WTG8.**

7.3 Field Methods General

A V102 Hemisphere vector antenna (or equivalent) will be deployed on the vessel to allow for accurate vessel heading as well as a differential position accuracy to within a meter. During mobilization, the navigator will conduct a positional accuracy check on the antenna by placing the antenna on a known GPS point and ensuring the antenna's position falls within a meter of the known coordinates. During operations, HYPACK Ultralite software will receive positional data from the antenna in order to direct the vessel to sampling stations.

The Field Lead Scientist will ensure that samples are taken according to the established protocols and that all forms, checklists, field measurements, and instrument calibrations are recorded correctly during the field sampling.

7.3.1 SPI/PV Field Data Collection

The SPI and PV cameras are state-of-the-art monitoring tools that collect high-resolution imagery over several meters of the seafloor (plan view) and the typically unseen, sediment–water interface (profile) in the shallow seabed. PV images provide a much larger field-of-view than SPI images and provide valuable information about the landscape ecology and sediment topography in the area where the pinpoint "optical core" of the sediment profile is taken. Unusual surface sediment layers, textures, or structures detected in any of the sediment profile images can be interpreted considering the larger context of surface sediment features. The scale information provided by the underwater lasers allows accurate density counts or percent cover of attached epifaunal colonies, sediment burrow openings, or larger macrofauna or fish which may have been missed in the sediment profile cross section. A field of view is calculated for each PV image and measurements taken of parameters outlined in the survey workplan.

Once the vessel is within a 5 m radius of the target location, the SPI/PV camera system will be deployed to the seafloor. As soon as the camera system has made contact with the seafloor the navigator will record the time and position of the camera electronically in HYPACK as well as the written field log. This process will be repeated for the targeted number of SPI/PV replicates per sampling station (i.e., eight at the turbine foundations, four at the SFEC). After all stations have been surveyed the navigator will export all recorded positional data into an Excel sheet. The Excel sheet will include the station name, replicate number, date, time, depth, and position of every SPI/PV replicate.

Acquisition and quality assurance/quality control of high-resolution SPI images will be accomplished using a Nikon D7100 or D7200 digital single-lens reflex (DSLR) camera with a 24.1-megapixel image sensor mounted inside an Ocean Imaging Model 3731 pressure housing system. An Ocean Imaging Model DSC PV underwater camera system, using a Nikon D7100 or D7200 DSLR, will be attached to the SPI camera frame and used to collect PV photographs of the seafloor surface at the location where the SPI images are collected. The PV camera housing will be outfitted with two Ocean Imaging Systems Model 400 37 scaling lasers. Co-located SPI and PV images will be collected during each "drop" of the system. The ability of the PV system to collect usable images is dependent on the clarity of the water column, the ability of the SPI system to collect usable images is dependent upon the penetration of the prism.

7.3.2 Acoustic and Video Data Collection

Targeted high-resolution acoustic surveys (SSS and MBES) will be conducted over the selected IAC corridors after boulder relocation and again after all construction has been completed to map boulder locations within the survey areas. Survey areas will include existing undisturbed boulder distributions in selected areas adjacent to the IAC corridor to facilitate comparison between disturbed and undisturbed boulders. Existing MBES and SSS data will be used to define the survey areas (Figures 12 and 13).

High resolution video and still images will be acquired at targeted hard bottom areas and turbine foundations with a small remotely operated video system (ROV) comparable to a Seatronics Valor ROV (https://geo-matching.com/rovs-remotely-operated-underwater-vehicles/valor). The positioning components of the ROV would include a surface differential positioning system, an Ultra Short Baseline (USBL), as well as ROV-mounted motion and depth sensors. The USBL transceiver will communicate with acoustic beacons mounted onto the ROV allowing for the vehicle's depth and angle in relation to the transceiver to be known. Adding in the motion and depth sensors on the ROV, all this information will be connected into the ROV navigation software simultaneously tracking both the vessel's position and the ROV's position accurately.

In addition to accurate ROV positioning components, the vehicle will be equipped with powerful thrusters in both horizontal and vertical directions, creating confidence for operating in areas with higher currents. The vehicle will also be equipped with several pilot aids including, auto heading, auto depth, and auto hover. Using these tools, the ROV cameras can focus on any specifically selected habitat features during the survey allowing for better visual observations by scientists. The ROV will also allow location of boulders independent of the vessel and without relying on the vessel speed. With an umbilical and ROV operator controls, the hard bottom habitats can be mapped thoroughly in a shorter time span than a towed video system.

The ROV will supply live video feed to the surface using HD video and UHD still cameras. One pair of cameras will be downward facing to observe and capture high resolution images of seafloor surface conditions while another pair will face forward to collect data on vertical surfaces and avoid collisions. Aiding in the visual data will be high lumen LED lights that will be mounted onto the ROV frame. With sufficient lighting the images transferred to the surface will be clear, allowing for real time observations and adaptive sampling. The recorded video will be transferred to the surface through the ROV's umbilical and recorded using a Digital SubSea Edge DVR video inspection system (or equivalent). The system will provide simultaneous recording of both high definition cameras as well as the ability to add specific transect data overlays during operations. The data overlay will include ROV positioning, heading, depth, data and time as well as field observations.

The ROV will also contain a manipulator arm and basket to collect voucher specimens of encrusting species to ensure accurate identification. Some species such as *D. vexillum* require microscopic investigation to accurately identify.

7.4 Data Entry and Reporting

Data management and traceability is integral to analysis and accurate reporting. The surveys will follow a rigorous system to inspect data throughout all stages of collection and analysis to provide a high level of confidence in the data being reported. Following data entry, all spreadsheets will be proofread using the original handwritten field log. This review will be performed by someone other than the data entry specialist.

SPI and PV image QC checks include comparison of date/time stamps embedded in the metadata of every SPI and PV image to the field log and navigation times to ensure that that all images are assigned to the correct stations and replicates. Computer-aided analysis of SPI/PV images will be conducted to provide a set of standard measurements to allow comparisons among different locations and surveys. Measured parameters for SPI and PV images will be recorded in Microsoft Excel© spreadsheets. These data will be subsequently checked by senior scientists as an independent quality assurance/quality control review before final interpretation is performed. Spatial distributions of SPI/PV parameters will be mapped using ArcGIS.

During field operations, daily progress reports will be reported through whatever means are available (email, text, phone). Upon completion of the survey all analyzed images as well as a data report with visualizations will be provided.

7.5 Data Analysis

7.5.1 Soft Bottom SPI/PV

Seafloor geological and biogenic substrates will be described from SPI/PV using the Coastal and Marine Ecological Standard (CMECS; FGDC, 2012). The Substrate and Biotic components of CMECS will be used to characterize sediments and biota observed. The SPI/PV image analysis approach is superior to benthic infaunal sampling approaches because SPI/PV is more cost effective and more comprehensive. Analysis costs for benthic biological characterization using SPI/PV can be up to 75% lower than those of infaunal abundance counts derived from grab samples. Infaunal abundance assessments provide a limited view of benthic conditions whereas SPI/PV provides a more holistic assessment of the benthos that includes the relationship between infauna and sediments (Germano et al., 2011). Although infaunal abundance values are not generated from SPI/PV analysis, lists of infaunal and epifaunal species observed in SPI/PV images, the percent cover of attached biota visible in PV images, presence of sensitive and invasive species, and the infaunal successional stage (Pearson and Rosenberg, 1978; Rhoads and Germano, 1982; and Rhoads and Boyer, 1982) will be provided as part of the benthic biological assessment.

Indicators of benthic function (bioturbation and utilization of organic material) include infaunal succession stage, feeding voids, methane, *Beggiatoa* and apparent redox potential discontinuity.

The boundary between colored ferric hydroxide surface sediments and underlying gray to black sediments is called the apparent redox potential discontinuity (aRPD). The aRPD is described as "apparent" because of the potential discrepancy between where the sediment color shifts and the complete depletion of dissolved oxygen concentration occurs due to the lag time between when the redox potential (Eh) reaches 0 millivolts (mV) and the precipitation of darker sulfidic sediments (Jorgensen and Fenchel, 1974). However, the mean aRPD measured in SPI is a suitable proxy for the RPD with the depth of the actual Eh = 0 horizon generally either equal to or slightly shallower than the depth of the optical reflectance boundary (Rosenberg et al., 2001; Simone and Grant, 2017). Factors that influence the depth of the aRPD include biological processes such as respiration and bioturbation and physical processes including advection and diffusion. The mean aRPD depth also can be affected by local erosion or physical disturbance. Scouring can wash away fines and shell or gravel lag deposits and can result in a very thin surface oxidized layer. In sandy sediments that have very low sediment oxygen demand (SOD), the sediment may lack a visibly reduced layer even if an RPD is present. Because the determination of the aRPD requires discrimination of optical contrast between oxidized and reduced particles, it is difficult, if not impossible, to determine the depth of the aRPD in well-sorted sands of any size that have little to no silt or organic matter in them. When using SPI technology on sand bottoms, estimates of the mean aRPD depths are often indeterminate with conventional white light photography. For these reasons, the SFEC transects will be located in sandy sediments with sufficient silt to measure aRPD.

Additionally, the benthic macrohabitat (*sensu* Greene et al. 2007) types observed in the SPI/PV survey of the project area will be described. Differences in abiotic and biotic composition of macrohabitats will be compared between pre- and post-construction surveys. In particular, composition and total percent cover of attached fauna on the scour mat and changes in benthic community with distance from the scour mat will be evaluated.

The approach for data analysis of the SPI/PV dataset will include modeling (e.g., GLM, GLMM, or GAM) of individual metrics that are consistently measured across stations (e.g., aRPD, Successional Stage, feeding voids). Covariates in the model for the turbine foundation dataset will include direction (categorical) and distance (continuous) from the turbine; variability among turbines will provide site-wide random error. Additionally, graphical methods and descriptive statistics will be used to assess changes in these metrics over time, as a function of distance and direction from the turbines. These graphical techniques may help to elucidate the spatial scale at which the greatest changes in benthic habitat quality occur.

7.5.2 Hard bottom Video

Video imagery will be reviewed during acquisition and observations will be logged to document biological species and geological features for each video transect. A video viewer will be used to view logs, photos and videos and confirm or add annotations. The system has the capability of taking stills from all the input video signals to document features of interest.

Hard bottom habitat quality will be summarized using the acoustic dataset. For each sampling frame rugosity, boulder height and the ratio of hard bottom to soft bottom habitat will be mapped and quantified. Video from ROV will be used to provide additional qualitative details of habitat quality including presence of fish and decapods, presence of refuge and surrounding substrata (sediment type).

Growth of macrobiotic cover will be summarized for each sampling frame from observations taken with the ROV survey. Mean macrobiotic cover and relative abundance of native vs. non-native species will be summarized for each sampling frame. The mean values may be statistically compared between disturbed and undisturbed areas, specifically for changes over time.

Table 6. Summary of planned analyses for the benthic monitoring surveys.

Report Section	Survey	Design type	Design Overview	Design details	Metrics of Interest	Research Question	Post-Construction Statistical Methods
7.1.2	Benthic Survey (SPI/PV) - SFW	BAG	Impact only (no reference sites); stns at distances ranging from ~10m to ~900m from turbines; 2 directions from each turbine along prevailing current (NE-SW); single season	**Sampling frame** = turbines with soft bottom in NE-SW directions **Observational unit** = SPI/PV station (turbines randomized first survey event, then fixed throughout study; stations randomized every survey; replicate images are subsamples) **Response variable** = mean or max per station depending on metric. **Error variance** = among stations at the same distance-direction (turbines provide replication)	**SPI**: aRPD, Successional Stage, penetration, methane, beggiatoa **PV**: cover (macrobiota, shells, cobble), presence/absence of sensitive or invasive species	What is the pattern of temporal change (B/A) in metrics relative to direction and/or distance from turbine?	Fit the GLM (or GLMM or GAM) that best describes the data; compare the coefficient (B/A) for the distance effect. Calculate similarity between stations; graphically depict relationships between stations from different years, directions, or distances with nMDS.
7.1.3	Soft Bottom Benthic Survey (SPI/PV) - SFEC	BAG	Impact only (no reference sites); stns at distances ranging from ~5m to ~1km from cable; 6 transects in each area with/without bottom disturbance from fishing activity; single season.	**Sampling frame** = two soft bottom areas of SFEC **Observational unit** = SPI/PV station (transects randomized first survey event, then fixed throughout study; stations randomized every survey; replicate images are subsamples) **Response variable** = mean or max per station depending on metric. **Error variance** = among stations at the same distance-direction (transects provide replication)	**SPI**: aRPD, Successional Stage, penetration, methane, beggiatoa **PV**: cover (macrobiota, shells, cobble), presence/absence of sensitive or invasive species,	What is the pattern of temporal change (B/A) in metrics relative to distance from cable?	Fit the GLM (or GLMM or GAM) that best describes the data; compare the coefficient (B/A) for the distance effect. Calculate similarity between stations; graphically depict relationships between stations from different years or distances with nMDS.
7.2	Hard Bottom Benthic Survey (ROV)	SS	Disturbed and Undisturbed at two WTGs; random samples; single season.	**Sampling frame** = Boulders within Disturbed and Undisturbed hardbottom near WTG1 and WTG8 **Observational unit** = imaged quadrat (on systematically sampled boulders within frame) **Response variable** = macrobiotic cover, relative abundance of native vs invasive. **Error variance** = among samples within same treatment (disturbed/ undisturbed) and turbine	**ROV**: cover (macrobiota, relative abundance of native vs. invasive).	What is the magnitude of difference in mean response between disturbed and undisturbed areas, at each survey event?	Estimate 90% CI on the difference of means for disturbed and undisturbed areas, at each survey event.

Definitions:
BAG = before after gradient
90% CI = 90% confidence interval
SS = Systematic (random) sampling

7.5.3 Regional Comparable Datasets

SPI/PV surveys have been conducted for the Block Island, South Fork, Revolution, and Sunrise Wind Farms, and their respective cable routes. Vineyard Wind has a drop camera survey planned for both of their offshore wind leases. The SPI/PV survey will be conducted using methods comparable to those developed by the UMASS Dartmouth School for Marine Science & Technology (SMAST) as part of a regional sea scallop survey (Bethoney and Stokesbury, 2018). The method has been utilized for other image-based surveys and is appropriate for this use. A camera system is dropped to the seafloor and samples four quadrats at defined stations in an area and captures digital images analogous to the PV images outlined above.

8.0 Data Sharing Plan

The fisheries monitoring data associated with the gillnet survey, beam trawl survey, ventless trap survey, fish pot survey, and benthic habitat monitoring are being stored and curated by Inspire Environmental. Fisheries monitoring data will be shared with regulatory agencies and interested stakeholders upon request. Data sharing will occur on an annual cycle, which may be unique to each survey, and all data will be subject to rigorous quality assurance and quality control criterion prior to dissemination.

Individuals seeking access to the data will be required to provide a formal written data request to Inspire Environmental. As part of the data request, a brief proposal will be required which includes a description of the data that is being requested (e.g., survey type, timeframe, geographic boundaries), the intended use of the data, a list of coauthors and their affiliations, and details regarding the anticipated products of the work (e.g., stock assessment, fishery management plan, thesis, manuscripts). Data Access Conditions and Protocols are also being developed, which will outline specific conditions associated with obtaining access to the data. Raw data (i.e., station level catch, biological data, and environmental data) can be requested, and will be distributed, provided that the criteria outlined in the Data Access Conditions and Protocols are met. In most cases, the SFW team anticipates that data requests can be accommodated electronically on an individual basis, and that individuals requesting data access will be given a unique username and password, which will be used to securely facilitate electronic data transfers.

The SFW team acknowledges that regional guidance related to data sharing and data storage for fisheries monitoring studies is being developed cooperatively through ROSA. To that end, the data sharing agreement outlined above may evolve over time as regional guidance is developed.

SFW will coordinate with our scientific contractor to host an annual workshop at the conclusion of each year of field work. This event will help to explain the methodology and disseminate the results of the monitoring and will provide a forum by which the project team can receive input and feedback. The event will be open to all regional stakeholders, but efforts will be made to encourage the attendance of regional fishermen, particularly those individuals whom have been contracted to conduct the field work.

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APPENDIX A
Record of Stakeholder Engagement

September 2020

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Date	Organizations/Individuals Contacted[1]	Location/Form of Contact and Response	Purpose of Contact	Summary of Key Comments[2]	Response Summary
11/14/18	BOEM, CFRF, CT DEEP, MA DMF, MA CZM, NMFS, NYS DEC, NYS DOS, NYS DPS, RI CRMC, RI DEM, RISAA, Individual fishermen	Emails from SFW and recipient responses are attached to Exhibit 1 to Appendix A	Distribution of Gillnet monitoring plan for comment	• Need for power analysis to determine level of sampling • Seasonal sampling inadequate • More specifics needed on gear used • More detail needed on survey of and impacts on specific species • Gillnets alone not enough to sample area	• Power analysis attempted but lack of comparable data prevents adequate analysis; later conducted for beam trawl and ventless trap survey (see Appendices B and D) • Monthly sampling added • Gear specifics added to plan • Additional gear types considered for sampling at SFWF; later incorporated into Fisheries Monitoring Plan (FMP) (Sections 3.0, 4.0, 5.0, 6.0, 7.0)
3/25/19	BOEM, CT DEEP, MA CZM, MA DMF, NMFS, NYS DEC, NYS DOS, RI DEM, USACE	Webinar; See Exhibit 2 to Appendix A	Review of FMP and received comments	• Additional sampling types needed including benthic • Better definition of research questions • Need to consider regional approach to sampling • More detail on how reference areas selected • Talk one on one with gillnetters to refine reference areas • Request for comment tracker	• Several other gear types under consideration for surveys; later incorporated into FMP • Regional research plan under development but permitting requirements dictate project-level plans • Language updated to address survey goals and selection of reference areas (Section 2.2) • Discussions lined up with gillnet fisherman (see below) • Comment tracker prepared

[1] BOEM – Bureau of Ocean Energy Management; CFCRI – Commercial Fisheries Center of Rhode Island; CFRF – Commercial Fisheries Research Foundation; CT DEEP – Connecticut Department of Energy and Environmental Protection; MA DMF- Massachusetts Division of Marine Fisheries; MA CZM – Massachusetts Center of Coastal Zone Management; MA FWG – Massachusetts Offshore Wind Fisheries Working Group; NEFMC – New England Fisheries Management Council; NOAA/GARFO - National Oceanic and Atmospheric Administration's Greater Atlantic Regional Fisheries Office; NOAA/NMFS – National Oceanic and Atmospheric Administration's National Marine Fisheries Service; NYS DEC – New York State Department of Environmental Conservation; NYS DOS – New York Department of State; NYS DPS – New York State Department of Public Service; NYSERDA – New York State Energy and Research Development Authority; RI CRMC – Rhode Island Coastal Resources Management Council; RI DEM – Rhode Island Department of Environmental Management; RISAA – Rhode Island Saltwater Angler's Association; RODA – Responsible Offshore Development Alliance; ROSA – Responsible Offshore science Alliance; SFW – South Fork Wind, LLC; USACE – United States Army Corps of Engineers

[2] Please see documents attached in the exhibits to this Appendix A for all the written comments received and considered. The purpose of this table in Appendix A is to present a summary of key comments received (written and verbal).

Date	Organizations/Individuals Contacted[1]	Location/Form of Contact and Response	Purpose of Contact	Summary of Key Comments[2]	Response Summary
3/26/19	RI CRMC	RI CRMC Offices, Wakefield RI	Review of FMP and received comments	• Agreed gillnet and beam trawl surveys are appropriate and will complement each other • Look at Anna Malek's thesis results • Consider highly migratory species (HMS), coordinate with hook and line and headboats	• Additional gears under consideration; later added to FMP (Sections 4.0, 5.0, 6.0, 7.0) • Thesis results utilized to assess beam trawl design • Support for HMS project later added to FMP (Section 6.0)
3/27/19	BOEM, CT DEEP, MA CZM, MA DMF, NMFS, NYS DEC, NYS DOS, RI DEM	Webinar; See Exhibit 2 to Appendix A	Review of FMP and received comments	• Need to consider regional approach to sampling • Good to include two reference areas • May be worthwhile to narrow scope of gillnet survey and target what is in the area and what data can be captured • Restrict gillnets to tie down and one mesh size • Opportunity to deploy acoustic receivers to gather more information on tagged species in area • Request to consider how to replace NMFS stock assessments	• Regional research plan under development but permitting requirements dictate project-level plans • Sampling may be restricted to spring/fall based on input from industry, may narrow focus to monkfish and skates; later updated to spring and fall sampling season and changed gear to one mesh size using tie downs in FMP (Sections 2.2, 2.3) • Acoustic telemetry is under consideration for additional monitoring; later incorporated into FMP (Section 6.0)
4/26/19	Capt. Greg Mataronas	ALWTRT meeting, Providence, RI	FMP; gillnet survey design	• Fleet does not fish in summer due to presence of sharks and sea turtles • No fishing in winter due to no catch and weather • Provided specifics on gear dimensions	• Modified sampling to spring/fall when commercial fleet fishes and to avoid interactions with protected species (Section 2.2) • Winter season eliminated; many other surveys do not fish when resources are not in area (BIWF lobster survey) (Section 2.2)

Date	Organizations/Individuals Contacted[1]	Location/Form of Contact and Response	Purpose of Contact	Summary of Key Comments[2]	Response Summary
				• Comparable reference areas will be difficult to locate	• Incorporated gear specifics into plan (Section 2.3) • Will reach out to additional industry and state agencies for input on comparable ref areas (see below)
6/13/19	BOEM, CFRF, CT DEEP, MA CZM MA DMF, MA FWG, NMFS, NYS DEC, NYS DOS, NYS DPS, RI CRMC, RI DEM, RISAA, Individual fishermen	Emails from SFW and recipient responses are attached to Exhibit 3 to Appendix A	Distribution of updated version of FMP for comment	• Beam trawl is good compromise as additional gear due to otter trawling not being possible at site • Adaptive sampling approach is good strategy in absence of background data for gillnet power analysis • Gillnet and beam trawl alone still not enough to adequately sample area • Acoustic monitoring should occur before, during, and after construction • Concern about maintaining control areas located in the wind farm lease area • Concerns with data-sharing among stakeholders	• Additional gears still under consideration for site; later added to FMP (Sections 4.0, 5.0, 6.0, 7.0) • Power analysis for beam trawl ongoing; see Appendix B
8/20/19	RI CRMC Habitat Advisory Board (HAB)	URI Coastal Institute, Narragansett, RI	Project update including fisheries monitoring	• Concerns with gillnet and protected species interactions in April/May • Consider acoustic receivers in use and placed on foundations in the future	• This is the time of year the gillnet fishery occurs in the area • Acoustic telemetry under consideration for additional monitoring; later added to FMP (Section 6.0)
9/9/19	RI CRMC Fishermen's Advisory Board (FAB)	URI Coastal Institute, Narragansett, RI	Project update including fisheries monitoring	• Surveys already too late as Geophysical and Geotechnical (G&G) vessels impacting area	• Important to continue to develop plan quickly to sample • Ensure reference areas outside of geophysical survey footprint

Date	Organizations/Individuals Contacted[1]	Location/Form of Contact and Response	Purpose of Contact	Summary of Key Comments[2]	Response Summary
				• Gillnet and beam trawl alone still not enough to adequately sample area • No consideration for recreational interests; particularly HMS; no rod and reel survey	• Additional gears still under consideration for site; later added to FMP (Sections 4.0, 5.0, 6.0, 7.0) • Rod and reel survey for cod did not result in many samples; difficult to standardize; Highly Migratory Species (HMS) are being considered, , candidate for acoustic telemetry; later added to FMP (Section 6.0)
9/19/19	Capt. Mike Marchetti	F/V Mister G, Point Judith, RI	Beam trawl gear overview and discussion	• Provided specifics on areas to tow and showed beam trawl used in previous work	• Details of gear incorporated into plan and tow areas considered in development of new reference areas (Sections 3.2, 3.3)
9/27/19	Capt. Mike Monteforte	F/V Second Wind, Point Judith, RI	Discuss otter trawling in SFW	• Provided tow tracks of area towed within SFW • Discussed time of year his target species occur in area	• Determined that based on his tow tracks, towable area is too narrow and short for conducting full survey • He only fishes at SFW for a short time period so not conducive to full year survey
9/30/19	RI CRMC FAB	URI Coastal Institute, Narragansett, RI; Subsequent communications with the RI CRMC FAB included in Exhibit 4 to Appendix A	Marine Affairs and FMP updates	• Sampling gillnet once per month is not enough, may miss things • Reference areas need to be relocated far from development areas • Lobster survey should be extended to Nov. as lobsters still around in numbers	• Sampling increased to twice per month; up to five strings per set (from two initially) (Sections 2.2, 2.3) • Work will be done to consult with industry members, agencies, and review other studies to identify suitable reference areas; conducted later and outlined in Exhibit 4 to Appendix A • Lobster survey protocol updated to include Nov. sampling
10/8/19	Capt. Mike Marchetti	F/V Mister G, Point Judith, RI	Overview of previous beam trawl work and reference site discussion	• Provided tow tracks and information on previous work • Identified areas appropriate for beam trawling to use as reference areas	• Information provided used in part to identify new reference areas for both gillnet and beam trawl outlined in Exhibit 4 to Appendix A

Date	Organizations/Individuals Contacted[1]	Location/Form of Contact and Response	Purpose of Contact	Summary of Key Comments[2]	Response Summary
10/29/19	RI DEM	RI DEM Offices, Jamestown, RI	Discussion on reference areas for fisheries monitoring	• Understands difficulties in designing gillnet survey and is happy with Ørsted's approach; beam trawl also a welcomed addition • Proposed Reference Area East should be moved north to accommodate rocky area • Expand on data sharing approach	• Reference Area East moved north to accommodate this recommendation (Sections 2.2, 3.2) • Data sharing language added to next version of FMP (Section 8.0)
11/7/19	RI CRMC	RI CRMC Offices, Wakefield RI	FMP update	• Suggest consulting with MA DMF on plan and reference site locations • Supportive of approach to identifying reference sites • Suggest another follow-up with RI DEM on power analysis approach	• Meeting scheduled with MA DMF to review plan and discuss control site locations; see below • Follow-up with RI DEM scheduled to discuss power analysis; see below
11/21/19	RI DEM	RI DEM Offices, Jamestown, RI	FMP power analysis	• Suggest sampling more in year 1 for gillnet then conduct power analysis on those data to determine subsequent sampling levels	• Adaptive sampling approach adopted for gillnet and beam trawl going forward
11/22/19	MA DMF	SMAST/MA DMF offices, New Bedford, MA	FMP overview	• Welcome opportunity to meet and be kept up to date • Important ventless survey methodologies line up across groups, data very important • Stomach content analysis important, glad to see it incorporated	• Ventless survey design still in development and will look to align with other regional surveys as much as possible; protocol later added to FMP (Section 4.0) • Monkfish and skate stomach analysis added to gillnet plan per MA DMF request (Section 2.4)
11/22/19	MA FWG	SMAST/MA DMF offices, New Bedford, MA	Project updates and FMP overview	• Will exempted fishing permits be needed for surveys?	• Letter of Acknowledgement (LOA) needed (confirmed by D. Christel from GARFO)

Date	Organizations/Individuals Contacted[1]	Location/Form of Contact and Response	Purpose of Contact	Summary of Key Comments[2]	Response Summary
				• There is a need for acoustic tagging • More gear types needed to monitor site	• Acoustic telemetry being considered and may support BOEM funded cod project currently underway; later added to FMP (Section 6.0) • Additional gears under consideration and in development; later added to FMP (Sections 4.0, 5.0, 6.0, 7.0)
11/26/19	CFRF, CFCRI	CFRF offices, Kingston, RI	FMP	• Gillnet and beam trawl not sufficient to sample area • Trawl survey should be conducted, talk with Capt. Monteforte • Fish pots also good gear to consider for structure associated species	• Additional gear types still under consideration, including fish pot; later added to FMP (Sections 4.0, 5.0, 6.0, 7.0) • Based on meeting with Capt. Monteforte trawl survey not possible as towable area is too narrow and short
2/6/20	RI DEM	RI DEM Offices, Jamestown, RI	Power analysis	• Current approach is good but worries level of sampling in year 1 is still too low; acknowledges determining what is enough is difficult • Would like species specific approach conducted in future analyses	• Will proceed as planned and adjust as actual survey sampling dictates if needed • Will conduct species specific analysis after year 1 when sufficient data are available
2/6/20	Capt. Ken Murgo	INSPIRE office, Newport, RI	Fish pot overview	• Provided fish pot gear overview and characteristics	• Information to be incorporated into potential fish pot protocol; later added to FMP (Section 5.0)
2/10/20	RI CRMC FAB	URI Coastal Institute, Narragansett, RI	Project updates and FMP	• Is distance of new reference sites adequate? • Suggest having workshop to formulate whole research plan that is amenable to all	• 24km from impact site considered sufficient. Acoustic studies suggest this distance is more than adequate • CFRF agreed to host workshop in March, SFW team will participate (see below)
3/11/20	CFRF, CRMC, RI CRMC FAB, NOAA/NMFS, RIDEM, RISAA, Vineyard Wind, Industry members	URI Coastal Institute, Narragansett, RI	Fisheries monitoring workshop	• Need to consider more gear types: rod & reel, acoustic telemetry, ventless trap, fish pot	• Protocols for ventless trap, fish pot, benthic monitoring (SPI/PV) and support for two regional telemetry studies all to be developed; later

Date	Organizations/Individuals Contacted[1]	Location/Form of Contact and Response	Purpose of Contact	Summary of Key Comments[2]	Response Summary
				• Sampling along cable routes must be considered • Largest effects may happen near turbines (European studies) so may consider Before-After-Gradient (BAG) study design for some surveys • G&G surveys having impacts, need to know effects of these surveys on fish	added to FMP (Sections 4.0, 5.0, 6.0, 7.0) • SPI/PV being considered for scallops on cable route, benthic habitat; later added to FMP (Section 7.3) • BAG design incorporated into fish pot and wind farm benthic survey designs (Section 5.0 and Section 7.0) • More information was gathered from site investigation team to incorporate into plan (Appendix C)
4/21/20	BOEM, NOAA/GARFO, NOAA/NMFS	Conference call	Protected species and permitting requirements	• Glad to see modifications to gillnet survey but may not be enough • Need more information on how takes will be handled • Ørsted must decide which surveys will apply for LOA or Exempted Fishing Permit (EFP) (longer process)	• In case of takes, will follow observer program sampling protocols, will add language to plan (Sections 2.3, 3.3, 4.3, 5.3) • Will work with contractor conducting the work to determine which permit is needed and they will apply • Gear modifications to reduce protected species interactions added to the plan (Sections 2.1. 4.1. 5.1)
5/11/20	BOEM, CT DEEP, MA DMF, NEFMC, NOAA/GARFO, NOAA/NMFS, NYS DEC, NYS DOS, NYSERDA, RI CRMC, RI DEM, RODA, ROSA, USACE	Emails from SFW and recipient comment responses are found in Exhibit 5 to Appendix A	Distribution of Final Fisheries Management Plan	• Comments and feedback solicited through agency webinar (see below)	• Includes gillnet and beam trawl surveys and updated with ventless lobster trap, fish pot BAG, benthic monitoring (cable and wind farm BAG), support for two acoustic telemetry projects
5/22/20	BOEM, CT DEEP, MA CZM, MA DMF, NOAA/NMFS, NYS DEC, NYS DOS, RIDEM	Webinar; See Exhibit 6 to Appendix A	Updated Final Fisheries Monitoring Plan	• Agencies requested to provide written comments on plan provided 5/11/20 (See Exhibit 5 for comments submitted; comments received from agencies	• Data Sharing Plan added to the Monitoring Plan (Section 8.0) • Substantial revisions made throughout plan following written comments • Addition of a summary table of research questions and statistical

Date	Organizations/Individuals Contacted[1]	Location/Form of Contact and Response	Purpose of Contact	Summary of Key Comments[2]	Response Summary
				between 6/9/20 and 7/13/20) • More details needed on adaptive sampling strategy • Power analysis needed for the ventless trap survey. • Data sharing needs to be clarified • Conductivity-temperature-depth profilers (CTDs) should be used to sample water column profile.	analyses (Sections 3.0, 4.0, 5.0, 7.0). Clarification of objectives • Power analyses performed for ventless trap survey (See Appendix D); further details provided on adaptive sampling design (Sections 2.6, 3.7, 5.7) • CTDs will be used to collect a vertical profile of the water column (Sections 2.5, 3.4, 4.4, 5.5)

APPENDIX B
Power Analysis for Beam Trawl Survey of Fish and Invertebrates

September 2020

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1.0 Introduction

For the beam trawl survey, a Before-After-Control-Impact (BACI) survey design is planned for the South Fork Wind Farm (SFWF), largely to capture benthic species and smaller fishes in this area where physical constraints make it difficult to survey using other gear types. EXA conducted an assessment for South Fork Wind, LLC and two topics are included within this appendix:

1. A review of an existing beam trawl dataset in the vicinity of the SFWF (Malek 2015) to establish the proximate range of a meaningful effect size in measuring change over time.
2. A power analysis for a BACI fish trawl survey using elements of time series of fish/invertebrate abundance collected using otter trawls during Block Island Wind Farm (BIWF) fisheries impact assessment surveys.

2.0 Power Analysis Elements

A statistical power analysis requires specification of the following:

- Study design specifics (i.e., number of replicates, number of sites, number of sampling events, number of years before and after construction), and their structure (e.g., random trawls as independent replicates within each site and sampling event, or fixed trawls nested within sites and repeatedly sampled over time).
- The statistical model, which is determined by the study design (previous bullet) and characteristics of the data (e.g., catch data as counts would be modeled with a generalized linear (potentially mixed) model with Poisson errors, or with a negative binomial if the count data are over-dispersed; presence/absence data would be modeled with logistic regression and binomial errors).

A statistical power analysis relates the following four elements; given three of these elements, the fourth can be estimated:

- **Effect size (Δ)** is the difference that the design and model will be able to identify as statistically significant. Statistical analysis of a BACI dataset relies on the interaction between any Before-After period differences and Control-Impact location differences to indicate when a significant impact has occurred. The effect size herein is expressed as the change between Before and After at the impact site that exceeds the change at the control site, expressed as a proportion of the impact site mean during the Before period. For example, an effect size of –0.3 could represent a 30% decrease in abundance at the impact site and no change at the control site; or a 50% decrease at the impact site and a 20% decrease at the control site; or other similar combinations that net a 30% difference.
- **Power (1-β**, where β is the Type II error**)** is the probability of rejecting the null hypothesis when the difference in the data exceeds a specific effect size (Δ_M). In the BACI design setting, it is the probability of finding the interaction term between Before-After periods and Control-Impact locations to be statistically significantly different from zero when an effect of size Δ_M is operating on the data.
- **Alpha (α)** is the Type I error, or the probability of rejecting the null hypothesis in error because the true difference is small (i.e., < Δ_M). The value α is typically fixed, at 0.05 or 0.10 (95% or 90% confidence). For power estimated through simulations, α is estimated as the percent of significant outcomes when the effect size imposed on the data was 0.

- **Sample size** encompasses the number of sites, replicates, and time periods sampled and determines the degrees of freedom for the statistical tests. All else being equal, as sample size increases, the precision estimates for the model parameters increase. This will result in higher power for a specific effect size, or a smaller detectable effect size for a specific level of power.

3.0 Review Existing Data

The Malek (2015) beam trawl dataset was used to establish a proximate range of a meaningful effect size in measuring change over time. The dataset was screened to only include:

- useable tows based on depth (Figure 1).
- relevant species (Table 1).

This dataset provides only a single survey per station in each sampling year: in November of 2010, and in August of 2011 and 2012. Catch from November surveys are expected to be in decline leading into the winter season, while August surveys are expected to be representative of the higher catch summer season. As such, this dataset provides a very limited view of the inter-annual temporal variance. The spatial variance among tows during each survey event is also contrasted with the spatial variance from the BIWF surveys that are used as a surrogate time series in the power analysis (Section 4.0).

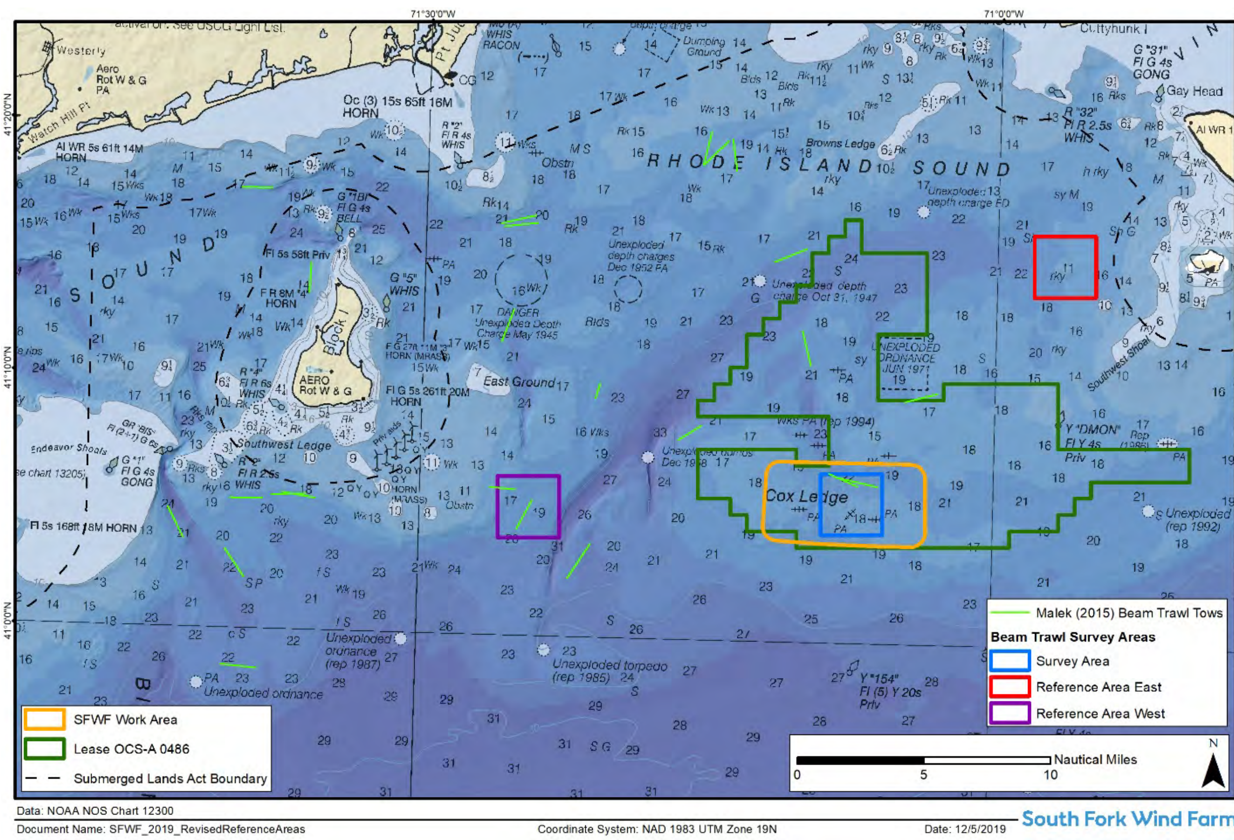


Figure 1. Map of Rhode Island Sound showing Malek (2015) tows from depths similar to the SFWF Work area, with proposed survey and reference sites.

Table 1. Individual Fish and Invertebrate species abundance from Malek (2015) that were used in this analysis

Fish	Total Abundance (all tows)		Invertebrate	Total Abundance (all tows)
Little skate	3251		Sea scallop	6496
Winter skate	1640		Sand dollar	4240
Skates (immature)	1187		Cancer crab	2638
Fourspot flounder	188		Starfish (mixed)	2545
Silver hake	153		Margined sea star	1488
Windowpane	122		Forbes sea star	1261
Red hake	88		Starfish	1256
Snailfish (Inquiline)	85		Boral sea star	935
Northern searobin	57		Pandalid shrimp	388
Gulf Stream flounder	55		Hermit crab	383
Winter flounder	51		Boreal sea star	359
Spotted hake	28		Longfin squid	270
Scup	26		Moon snail	189
Monkfish	20		Sea cucumber	61
Summer flounder	19		American lobster	39
Yellowtail flounder	15		Ocean quahog	34
Sea raven	12		Blue mussel	31
Longhorn sculpin	9		Blood star	24
Barndoor skate	8		Surf clam	20
Striped searobin	6		Conch (channeled whelk)	10
Black seabass	5		Sea mouse	9
Ocean pout	5		Waved whelk	7
Butterfish	2		Cockle	6
Cunner	2		Spider crab	6
Pipefish	2		White sea cucumber	6
Smallmouth flounder	2		Sea urchin	5
Spiny dogfish	2		Rat tailed sea cucumber	3
Atlantic torpedo	1		Horse mussel	2
Haddock	1		Orange footed sea cucumber	2
			Conrad's thracia	1

A summary of the total abundance for the species shown in Table 1 at the tows shown in Figure 1 is presented by year in Table 2 and Figure 2. There were two tows from 2010 that had catch that was 3.5 to 6.5 times higher than the next highest tow from that year. These outliers have a large effect on the outcome of the expected differences over time; but only four stations would remain if they were excluded. Consequently, they were retained in the analysis but their influence is noted.

Table 2. Summary of abundance data by year in beam trawl dataset (Malek 2015), with and without outliers from 2010.

Month - Year	Station	Total Abundance			
		Range	Mean	Std. Dev.	CV
Nov - 2010	OFF1[a]	5356	-	-	-
	PG1 [a]	2941	-	-	-
	Remaining Stations (n=4)	231 - 817	539	306	0.6
	All Stations (n=6)	231 – 5356	1742	2028	1.2
Aug - 2011	All Stations (n=9	597 – 2771	1399	762	0.5
Aug - 2012	All Stations (n=13)	52 - 1280	516	347	0.7

CV = Std. Dev. / Mean
[a] Observations represent extreme values

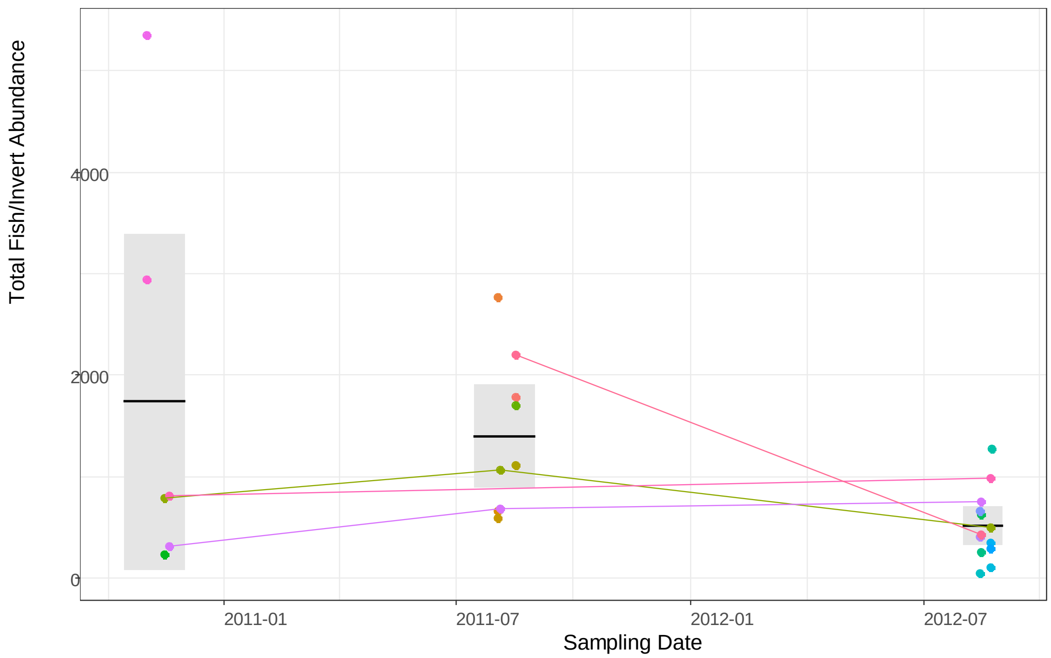


Figure 2. Total abundance for each station by date (from a single tow per date). Lines connect stations that were revisited over time. Gray bars cover the annual mean ± 2* SE, and the black line intersecting each bar is the mean of all stations for that year.

3.1 Methods

A meaningful *Effect Size* is one that is greater than differences commonly seen among control sites. The inter-annual differences in catch based on the single month beam trawl surveys provide very rough estimates of the magnitude of changes seen from natural variability. Meaningful *Effect Sizes* for the study design could not be expected to be smaller than natural variability. The range of natural variability was estimated using a bootstrap approach that assumes that all trawls in the Malek (2015) dataset are independent observations from the same population. Bootstrap estimates of differences in survey means (i.e., average of multiple tows from different areas on a single date) were calculated. Bootstrapping from the control area dataset of Malek (2015) used the following approach:

1. Randomly select k (k = 2, 3, or 4) trawls from each year *t* (*t* =2010, 2011, 2012). Note: The trawls are drawn independently from each year, with replacement.
2. Compute the annual average of the k trawls from each year, $\bar{X}_t$ for *t* =2010, 2011, 2012
3. Calculate and save the temporal differences, and calculate the change in means from year to year, as a proportion of the baseline year, i.e.,

$$Natural\ Temporal\ Change = (\bar{X}_{Yr2} - \bar{X}_{Yr1})/\bar{X}_{Yr1}$$

4. Repeat Steps 1-3 3000 times for each k. This will result in 3000 representations of the temporal differences in means of k trawls from a Control area.

3.2 Results

Results for the bootstrap estimates of the natural temporal change for k = 2, 3, or 4 replicates are shown in Figure 3 and summarized in Table 3. The median values of these nine bootstrapped distributions ranged from -0.7 to +0.6. The median values represent the central tendency without being overly influenced by individual high values. The 2010 survey had two extreme values which strongly influenced the annual means from this year; in addition, the 2010 survey was conducted in November, whereas the other two surveys were conducted in August, so the 2010 data introduce additional uncertainty due to the seasonal differences. The results between the August 2011 and August 2012 surveys are not confounded by seasonal differences, so these results may be most informative, albeit on a limited temporal scale. Temporal change estimates representing inter-annual August differences (and including spatial variability with k=2, 3, or 4) ranged from -0.8 to -0.5 (Table 3).

Table 3. Minimum, median and maximum temporal change estimates from bootstrap replicates shown in Figure 3.

Proportional Change[a] calculated between years	2 replicate tows			3 replicate tows			4 replicate tows		
	Min	Median	Max	Min	Median	Max	Min	Median	Max
2011 – 2010	-0.3	0.4	4.1	-0.3	0.4	4.1	-0.3	0.6	4.1
2012 – 2010	-0.8	-0.6	0.5	-0.8	-0.6	0.5	-0.8	-0.5	0.5
2012 – 2011	-0.8	-0.7	-0.5	-0.8	-0.7	-0.5	-0.8	-0.7	-0.5

[a] Proportional temporal change calculated as $(\bar{X}_{Yr2} - \bar{X}_{Yr1})/\bar{X}_{Yr1}$

The observed August differences between adjacent years for the BIWF data ranged from -0.8 to +3.6 (Table 4). The observed year-to-year differences within the same area support using multi-year surveys to measure abundance within each "Before" or "After" period. The differences using 2-year averages with 12 surveys per year are much less variable and range from -0.6 to +0.5 across the two reference areas (Table 4). While these values provide a very limited context for what level of temporal change may be natural for control sites away from a specific impact, the indication is that values much smaller than -0.6 or -0.5 may be untenable as a target effect size.

Table 4. Summary of annual BIWF fish survey results for total abundance, with estimates of natural temporal change

		August Value				12 Month Mean			
		Total Abundance		Temporal Change (single year)[a]		Total Abundance		Temporal Change (2 yr means)	
Year	Calendar Year	REF-E	REF-S	REF-E	REF-S	REF-E	REF-S	REF-E	REF-S
1	Oct 2012 – Sep 2013	3169	1048			6142	743		
2	Oct 2013 – Sep 2014	1185	239	-0.63	-0.8	4487	485		
3	Oct 2014 - Sep 2015	1129	1089	-0.05	3.6	1911	782		
4	Oct 2015 – Sep 2016	2392	2362	1.12	1.2	2043	1028	-0.63	0.5
5	Oct 2016 – Sep 2017	1285	3299	-0.46	0.4	1348	886	-0.47	0.5
6	Oct 2017 – Sep 2018	4204	915	2.27	-0.7	1975	703	-0.16	-0.1
	Minimum			-0.8				-0.6	
	Median			0.2				-0.1	
	Maximum			3.6				0.5	

[a] Single year temporal change calculated as $(\bar{X}_t - \bar{X}_{t-1})/\bar{X}_t$. Temporal change based on two year means calculated as $(\bar{X}_{t:t+1} - \bar{X}_{t-2:t-1})/\bar{X}_{t-2:t-1}$

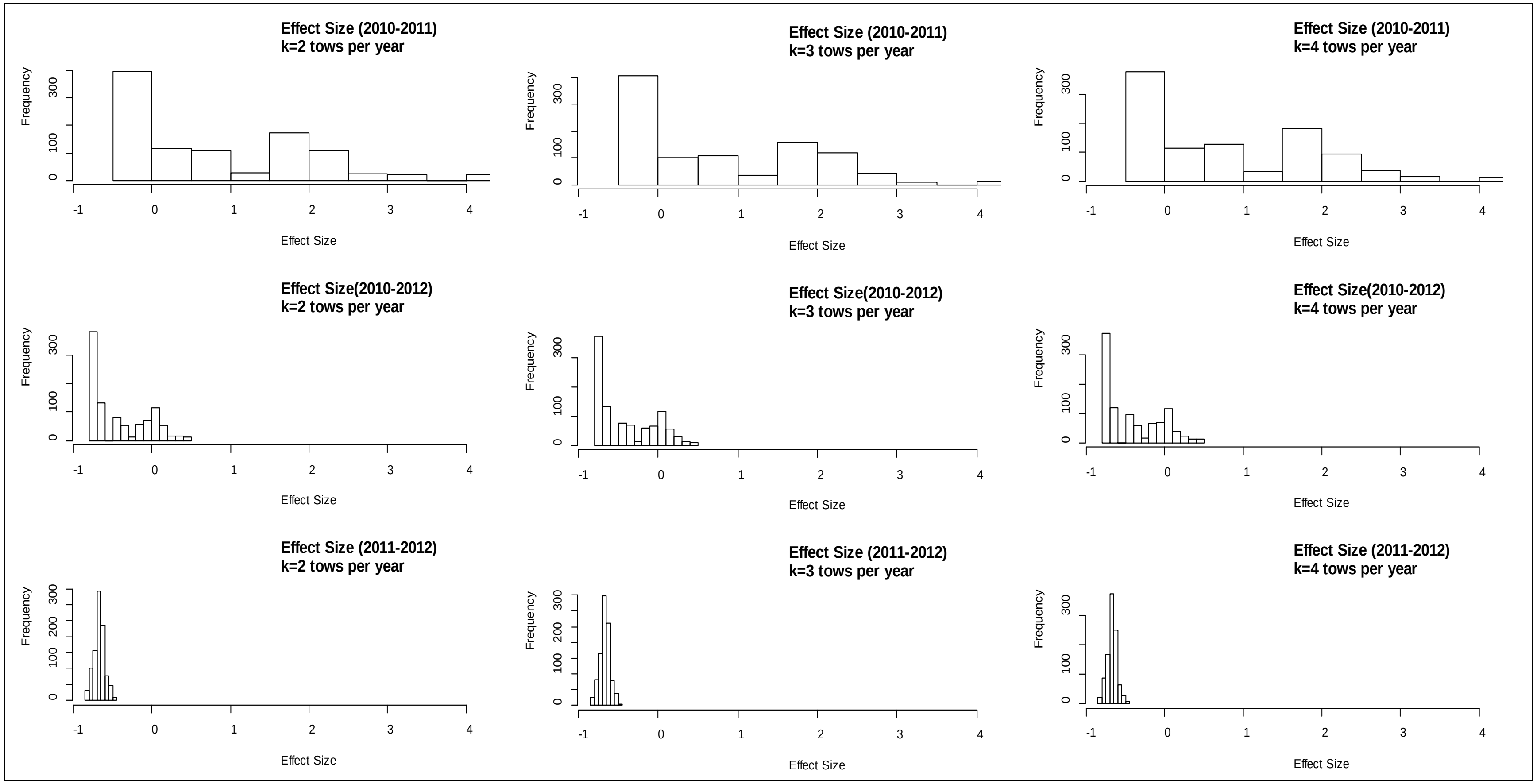


Figure 3. Bootstrap distributions (m=3000) of "effect sizes" for the differences in annual means as a percent of the "before" year. The three rows show three pairwise combinations of annual means, and three columns show different number of tows (for k=2, 3, and 4). Each annual mean is derived from k tows on a single survey date in the screened Malek (2015) dataset.

4.0 Power Analysis Methods

Statistical power was estimated using the program *epower* (Fisher et al. 2019), which requires pilot "Before Impact" data to estimate the posterior probability of model parameters in a Bayesian framework; the "After Impact" data are then simulated from these posterior probabilities under the effect size specified by the user. "Before" datasets that captured realistic spatial and temporal variability were needed for this analysis. The Malek (2015) beam trawl dataset provided estimates of total abundance and synoptic spatial variability among independent tows; these data were used to estimate natural temporal change as frame of reference for reasonable effect sizes to target in the SFWF beam trawl survey. However, in the Malek dataset the level of replication over time was insufficient to estimate temporal variability at the scale needed for the power analysis (i.e., intra-annual variance at a monthly scale, and inter-annual variance over multiple years). Consequently, the BIWF fish trawl datasets were mined for estimates of temporal variability. The BIWF dataset provides a 6-year time series of monthly observations at two reference areas (REF-E and REF-S), and one area of potential impact (APE) (Figure 4).

Year-to-year differences are present within each of the areas sampled from the BIWF dataset, particularly in the period 2013 to 2015 (Figure 4). The Malek survey did not overlap temporally with the BIWF survey so catch data from the two datasets represent different years as well as very different sampling frequencies and gear types. The magnitude of total catch values from the two datasets are not dramatically different for surveys from the same months (i.e., November or August) in most years (Table 5). This comparability is important since the BIWF time series will be used as a surrogate for the beam trawl surveys. The spatial variability within survey events of the Malek beam trawl surveys was moderate with CV values in the range 0.5 to 0.7 (or up to 1.2 if the 2010 outliers were included; Table 2). These values are within the range of CV values observed among spatial areas within the BIWF dataset, which ranged from 0.01 to 1.12 for August and November surveys (Table 5).

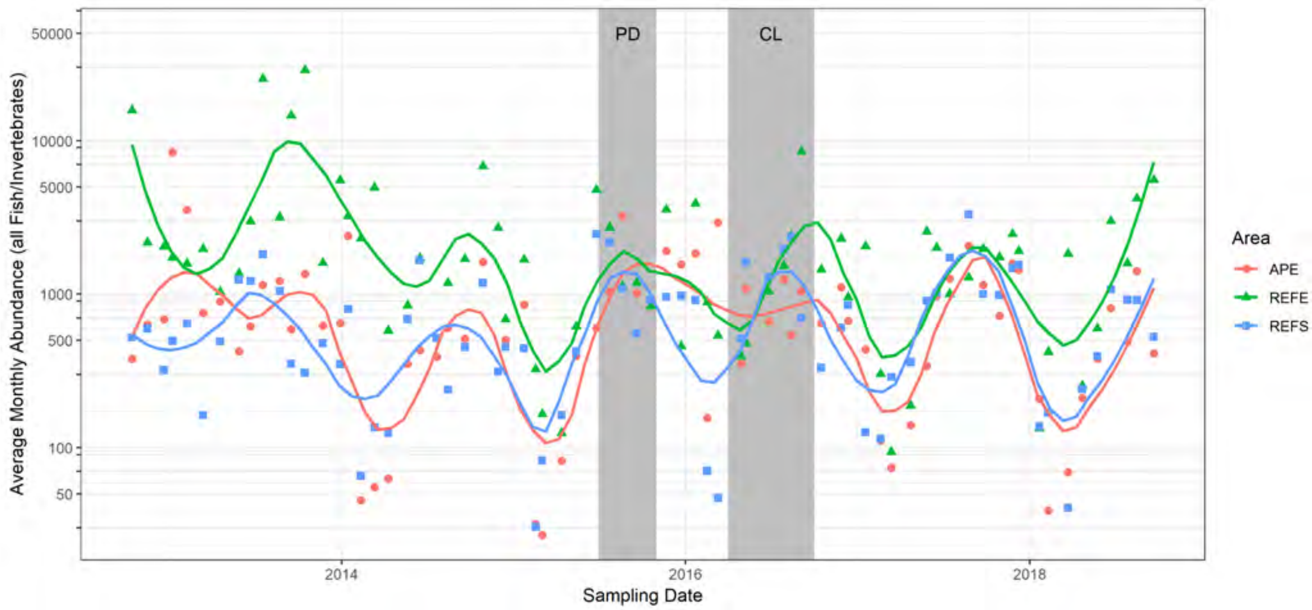
Table 5. Summary of annual mean (October – September) and November and August total abundance for BIWF otter trawl datasets at reference areas and the Malek (2015) beam trawl dataset

Year	Calendar Year	12 Months		November			August		
		REF-E	REF-S	REF-E	REF-S	CV[a]	REF-E	REF-S	CV
1	Oct 2012 – Sep 2013	6142[b]	743	2171	598	0.79	3169	1048	0.65
2	Oct 2013 – Sep 2014	4487	485	1597	480	0.67	1185	239	0.71
3	Oct 2014 - Sep 2015	1911	782	2716	313	1.12	1129	1089	0.03
4	Oct 2015 – Sep 2016	2043	1028	3566	961	0.81	2392	2362	0.01
5	Oct 2016 – Sep 2017	1348	886	2302	603	0.83	1285	3299	0.62
6	Oct 2017 – Sep 2018	1975	703	2463	1477	0.35	4204	915	0.91
6-Year BIWF Average		**2984**	**771**	**2469**	**739**	**0.76**	**2227**	**1492**	**0.49**
Minimum		1348	485	1597	313	0.35	1129	239	0.01
Median		2009	763	2383	601	0.80	1839	1069	0.64
Maximum		6142	1028	3566	1477	1.12	4204	3299	0.91
Beam Trawl Mean (2010 – 2012) [c]				**1219** (1 year)			**958** (2 years)		
Excluding outliers				**818** (1 year)					

[a] CV = coefficient of variation (standard deviation / mean) between areas within each year. The CV for years 1 and 2 include values for the APE (not shown).

[b] The data series in year 1 for REF-E had several extreme values (see Figure 4); the time series components for REF-E data excluding this year were also estimated.

[c] Data extracted from Malek (2015), as summarized in Table 2, shown here for some context in how total catch differed spatially and temporally for the two datasets.



Note: PD = pile driving and CL = cable laying

Figure 4. Time series for fish trawl data sets from the BIWF area of potential impact (APE) and two reference areas. Temporal patterns in the data are highlighted with a smoothing function (i.e., loess, span=0.20).

4.1 Estimate time series components

The time series attributes (i.e., stationarity, autocorrelation, seasonality) were estimated for the BIWF otter trawl data set from the REF-S reference area to simulate data for one of the variance scenarios used in the power simulations (Sections 4.2 and 4.3). Area REF-S was selected for modeling because it had the most consistent patterns from year-to-year (blue line, Figure 4), and therefore would provide the best-fitting model without the need to de-trend the series or remove extreme values. An auto-regressive integrated moving average (ARIMA) time series model with log-normal errors was estimated in R (R Core Team, 2019) using *forecast::auto.arima* (Hyndman et al. 2019 and Hyndman and Khandakar 2008), and simulations from the model were made using *sarima::sim_sarima* (Boshnakov and Halliday 2019*)*. A description of the best-fitting time series model is presented in Table 6. Two-year time series simulations from this model were added to two different reference area mean abundance values to simulate references for scenario #2 in Section 4.2.

Table 6. Summary of best fit time series model for BIWF REF-S otter trawl dataset

Area Modeled	Time Series Length	Best model from auto.arima()	General Description
REF-S	6 years	ARIMA(0,0,1)(1,0,0)[12] with non-zero mean	Stationary series with a moving average (lag 1) smoothing function; seasonal pattern (1,0,0) is auto-regressive (lag 1) for 12 seasons per year. Mean = 761 and sigma = 518.

4.2 Construct alternative time series scenarios

Four alternative time series scenarios were developed to represent pilot data for the "Before" time period. The time series scenarios are intended to model the potential range of spatial-temporal variability in future beam trawl data, with the purpose of estimating how this variability affects the power to detect a meaningful effect. The higher the spatial-temporal variability in catch data, the harder it is to confidently detect a difference that is meaningful. These four time series scenarios were based on the BIWF dataset, because this dataset is the closest analogue available for the South Fork area.

The time series for the impact site was unchanged in the four variance scenarios; only the mean and variance for the two reference areas were altered. Because the effect size is expressed as a proportion of the mean abundance at the impact site during the Before years, keeping the impact time series unchanged in these four different scenarios means that the relationship between the proportional effect size and the magnitude of total abundance stays constant across all scenarios. **In all four scenarios, the impact site was represented by the observed time series from years 5 and 6 (October 2016 to September 2018) for the APE block**, while two reference area time series were extracted or simulated from the BIWF time series as described below. The data for each area in these four alternative scenarios are graphically presented in Figure 5; summary statistics are presented in Table 7.

1. **Variance Scenario #1** used the observed time series from years 5 and 6 (October 2016 – September 2018) from BIWF reference areas (REF-S and REF-E). During this 2-year period, the time series from the impact and two reference areas were very similar, with minimal spatial variance and similar temporal variance among areas. Temporal-spatial interactions were also minimal.

2. **Variance Scenario #2** used the BIWF reference area surveys from years 5 and 6 with intra-annual and spatial variance increased through multiplying REFE abundances by a factor of 1.5, and REFS abundances by 0.5. Spatial variance is increased from the variance scenario #1, but temporal-spatial interactions remain minimal.

3. **Variance Scenario #3** used a simulated 2-year time series modeled from the temporal patterns observed in BIWF REF-S survey (Section 4.1), applied to two different reference means. Spatial variance is increased relative to variance scenario #1; intra-annual temporal variability is reduced and temporal-spatial interaction is increased relative to variance scenario #2.

4. **Variance Scenario #4** used the observed time series from years 1 and 2 (October 2012 – September 2014) from the BIWF reference areas (REF-S and REF-E). During this two year period there was substantial spatial and temporal variance, as well as temporal-spatial interaction.

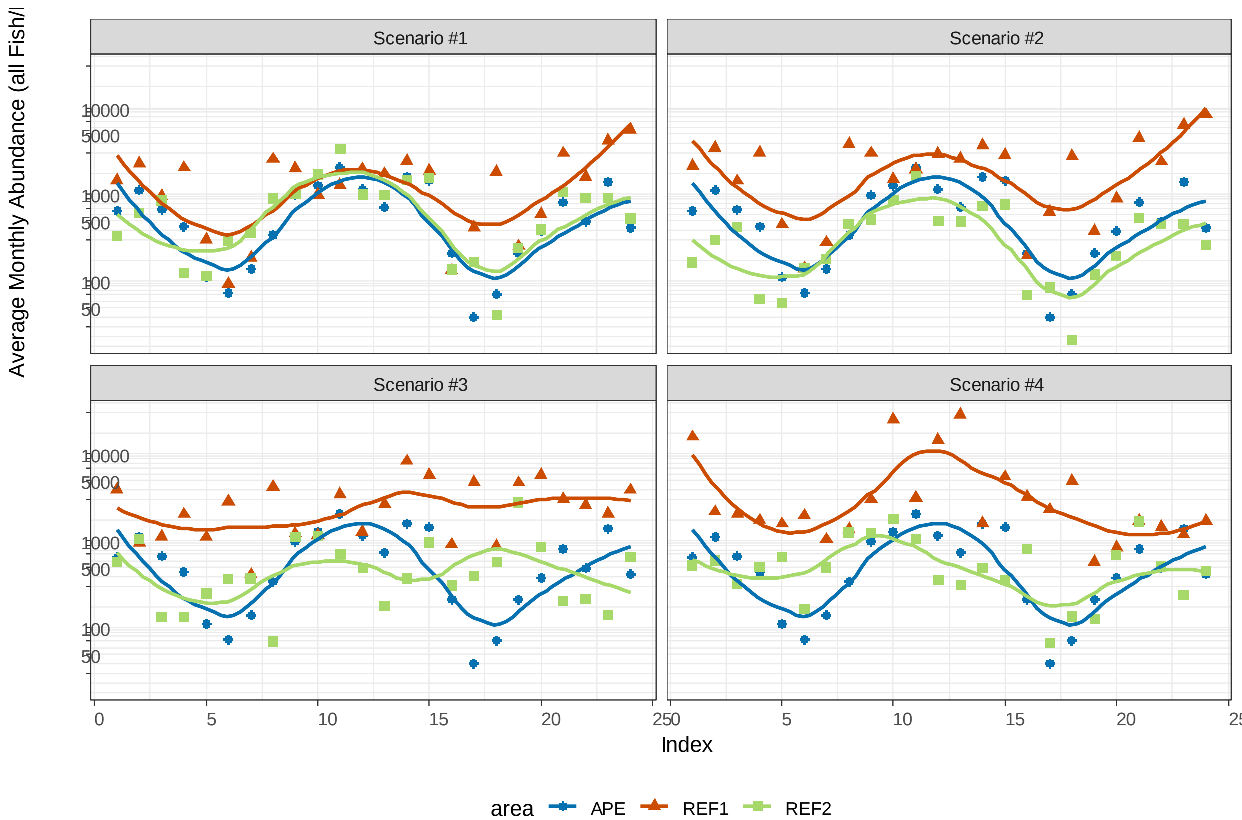


Figure 5. Time series for the four scenarios used in power simulations.

Table 7. Summary statistics[a] of total catch by area under the four alternative variance scenarios

	Scenario #1			**Scenario #2**			**Scenario #3**			**Scenario #4**		
	Mean	**SD**	**CV**	**Mean**	**SD**	**CV**	**Mean**	**SD**	**CV**	**Mean**	**SD**	**CV**
Impact	698	562	81%	698	562	81%	698	562	81%	698	562	81%
REF 1	1661	1324	80%	2492	1986	80%	2877	1982	69%	5314	7735	146%
REF 2	794	721	91%	397	361	91%	585	574	98%	614	469	76%
Standard Error of Means (n=3)	530			1133			1292			2690		

[a] Mean = average over 2 years; SD = standard deviation over 2 years (ignoring autocorrelation and assuming independence); CV = coefficient of variation = SD/mean x 100.

4.3 Estimate power using *epower* program

The *epower* program (Fisher et al, 2019) was initially run using 100 Monte Carlo simulations for each of the four scenarios used to describe the "Before Impact" period. Using 100 simulations provides preliminary results to highlight the patterns observed in the estimated power for various design and data scenarios. Three hundred simulations were run for effect sizes of -0.5 to refine the power estimates in this effect size range.

The model fit to the data is defined below, using model notation consistent with the notation used in Fisher et al (2019). Total abundance (Y) is modeled as a function of fixed and random effects using a generalized linear mixed model (GLMM). Y is distributed as a negative binomial variable, and the logarithm of its expected value (E[Y]) can be modeled as a linear function of the fixed and random effects.

$$log(E[Y(iltj)]) = \mu + u(l) + v(t) + k(lt) + z([t]j) + p(lj)$$

$$\mu = \beta_0 + \tau + \kappa + (\tau\kappa)$$

Where

$Y(iltj)$	=	total abundance in replicate (tow) *i* from location (or block) *l*, time (or year) *t*, subtime (or month) *j*
β_0	=	grand mean as intercept
τ	=	Before-After fixed effect
κ	=	Control-Impact fixed effect
$(\tau\kappa)$	=	fixed effect for BACI interaction term
$u(l)$	=	random effect for location *l* (*l*=1, 2, 3 for APE, REF1, and REF2)
$v(t)$	=	random effect for time (year) *t*
$k(lt)$	=	random effect for interaction between location *l* and time *t*
$z[t]j$	=	random effect for subtime (month) *j* nested within time (year) *t*
$p(lj)$	=	random effect for interaction between location and subtime

The basic study design for the SFWF beam trawl survey is described in Table 8 by the set design variables. The number of replicate tows per station per sampling event was varied in this analysis to explore how statistical power was affected by sampling effort. This analysis focused on total abundance as the response variable to be tested.

Table 8. Study design for SFWF beam trawl survey

Set design variables
• Impact Areas = 1 impact block
• Control Areas = 2 control/reference blocks
• Habitat Strata = 1 (a single stratum for habitat type was dominant within the areas that are fishable with the beam trawl)
• Frequency = once per month at each station (12 sampling events per year)
• Number of years Before impact = 2 • Number of years After impact = 2
Variables altered in the power analysis:
• Number of replicate tows (or stations) = 2, 3, or 4 tows per area per sampling event. Each tow represents a newly selected random station.

The variables altered in the power analysis (Table 8: three levels of replication) resulted in three different alternative designs. Power simulation results for the four alternative variance scenarios under these three alternative designs are shown in Table 9. The following conclusions can be made:

- Effect Size of 0 was used to estimate the Type I error (α) for each model and data scenario. For all scenarios, the type I error rate was a maximum of 1%, less than the nominal 5% Type I error rate that is typically used. A low Type I error indicates that spurious interaction effects are unlikely to be detected. The testing approach appears to be robust[1].

- Effect Size of -0.3 was found to have low power (< 50%) for all scenarios tested. This is not unexpected given the range of temporal differences observed in the bootstrapped results for the beam trawl survey and the BIWF dataset (Tables 3 and 4).
- Effect Size of -0.5 was found to have relatively high power (≥ 80%) for 3 and 4 replicate tows for Variance Scenarios #1 and #3, but only for the highest level of replication in the other two scenarios. The power results that are close to 80% could be tested with a larger number of simulations (m ≥ 500) in order to have greater confidence in these outcomes. Once power estimates are above 90% the marginal increase in power is less important.
- Effect Size of -0.7 resulted in high power (≥ 90%) for all of the designs for all four of the alternative variance scenarios tested. This provides assurance that the method and designs are capable of detecting fairly large effects (consistent with natural temporal variability) with consistently high power.

Table 9. Output from *epower* program estimating the power for three different model designs under four effect sizes for four alternative variance scenarios

Alternative Model Design[a]	Number of replicate tows	Type I error (α) Variance Scenario #1	Variance Scenario #2	Variance Scenario #3	Variance Scenario #4
Effect Size = 0 (100 sims)					
1	2	0	0	0	0
2	3	0	0	0	0
3	4	0	0.01	0	0

Alternative Model Design[a]	Number of replicate tows	Power Variance Scenario #1	Variance Scenario #2	Variance Scenario #3	Variance Scenario #4
Effect Size = -0.3 (100 sims)					
1	2	0.09	0.09	0.09	0.08
2	3	0.24	0.11	0.12	0.12
3	4	0.41	0.16	0.19	0.19
Effect Size = -0.5 (300 sims)					
1	2	0.79	0.51	0.65	0.46
2	3	0.93	0.72	0.83	0.66
3	4	1	0.82	0.95	0.87
Effect Size = -0.7 (100 sims)					
1	2	NT	0.99	0.98	0.97
2	3	NT	1	1	1
3	4	NT	1	1	1

[1] The same result was found by Fisher et al (2019) in their case studies. So, this robustness may be a function of the method rather than specific to the data.

[a] All model designs used the following: one impact block; two control blocks; one habitat stratum; monthly tows at each station (12 tows per year); two years of sampling Before and After the impact event.

5.0 Summary and Conclusions

As expected, increasing survey effort (i.e., more replicate tows) will increase the power to detect a given effect size. Variance Scenario #1 explored here was the last two years of the observed BIWF time series for the otter trawl surveys, representing realistic variance scenarios for fish trawl surveys in Rhode Island Sound. Three replicates resulted in high power (≥ 90%) to detect effect sizes of 0.5 or greater for this realistic variance scenario.

The power for the SFWF beam trawl surveys will depend on how the variance in those surveys compares to the surrogate variance scenarios explored in this analysis. Surveying SFWF using a survey design that samples monthly for 2 years before construction at 1 impact and 2 control locations, with three replicate stations per location will provide information similar to what was used in this power analysis, but specific to the SFWF impact assessment with a focus on the particular species of interest. After the first two years of the beam trawl surveys, this type of power analysis should be revisited to determine whether additional sampling effort during the After period is needed to achieve sufficient power given the actual spatial-temporal variability in the beam trawl catch.

Acknowledgements

Analyses were carried out using the software ‘epower’ V1.3 (BMT 2019) as described in Fisher et al (2019) and (BMT 2019) and based on the statistical programming platform R (R-Core Team, 2019). ‘epower’ has been developed jointly by BMT, the Australian Institute of marine Science and Queensland University of Technology. BMT, the Australian Institute of Marine Science and Queensland University of Technology accept no liability or responsibility for in respect of any use of or reliance upon this software.

6.0 References

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APPENDIX C
High-Resolution Geophysical Surveys and Fisheries Monitoring Surveys

September 2020

South Fork Wind | Powered by Ørsted & Eversource

High-Resolution Geophysical (HRG) surveys are conducted by wind energy developers for site investigation to inform engineering and design. These surveys are also required by the Bureau of Ocean Energy Management (BOEM) for offshore wind development activities. Some stakeholders have raised the question about any spatial and temporal overlap of HRG surveys with fisheries monitoring surveys and whether HRG survey equipment potentially affects the behavior and distribution of marine taxa. Several points address this matter.

First, seismic air guns, which studies have shown can influence the distribution and catch rates of commercially important marine fish (e.g., Lokkeborg and Soldal, 1993; Engas et al., 1996), are not used during HRG surveys for offshore wind development. HRG surveys may employ a variety of different equipment, other than seismic air guns, that operate at a wide range of frequencies (Table 1). The acoustic characteristics of representative HRG survey equipment is well known, as shown in Table 1, which incorporates data from a recent study funded by BOEM to independently measure and verify the noise levels and frequencies of HRG equipment (Crocker and Fratantonio, 2016). Additional field studies have been conducted and are in review.

Second, well established audiograms have been used to understand the hearing sensitivities for a number of species of fish (Table 2). Fish have been classified into four groupings based on their physiology and their presumed hearing sensitivity (Hawkins et al., 2020). Of the HRG equipment that is commonly employed, 'sparkers' and 'boomers' operate at the lowest range of frequencies. As noted by Nedwell and Howell, (2004) there have been no animal reaction studies to determine how marine taxa respond to the boomers and sparkers that are used during HRG surveys, although Kikuchi (2010) suggested that sparkers and boomers may affect the behavior of cod due to the overlap between the hearing sensitivities of cod and the operational frequency of the equipment. Ørsted will not use 'sparkers' and/or 'boomers' in the South Fork lease area in the fall or winter of 2020 when fisheries monitoring surveys are expected to commence.

Third, for the remainder of 2020, the only HRG equipment that Ørsted plans to use in the SFWF lease area are non-intrusive parametric sub-bottom profilers and USBL acoustic positioning systems. The parametric sub-bottom profilers all operate at a frequency of $\geq$ 60 kHz, while the USBL's operate at a frequency of $\geq$ 17 kHz (Table 1; Ørsted, 2019). Given that the operating frequencies of these HRG equipment are well outside the auditory range of nearly all species in the region, these HRG surveys are expected to have a negligible impact on the fisheries monitoring surveys. While the HRG equipment is likely to change over time, as stated above, Ørsted commits that seismic air guns will never be used for site investigations surveys. The Ørsted site investigations team records the time, date, and location that each piece of HRG equipment is deployed during site investigations surveys.

Finally, Ørsted anticipates that there will be periods of time with no spatial overlap between HRG surveys and fisheries monitoring surveys.

Table 1. Summary of the operating frequencies and source levels of HRG equipment authorized for use under the approved 2019 Ørsted IHA application.

Representative HRG Survey Equipment	Range of Operating Frequencies (kHz)	Baseline Source Level a/	Representative RMS_{90} Pulse Duration (millisec)	Pulse Repetition Rate (Hz)	Primary Operating Frequency (kHz)
USBL & Global Acoustic Positioning System (GAPS) Transceiver					
Sonardyne Ranger 2 transponder b/	19-34	200 dB_{RMS}	300	1	26
Sonardyne Ranger 2 USBL HPT 5/7000 transceiver b/	19 to 34	200 dB_{RMS}	300	1	26
Sonardyne Ranger 2 USBL HPT 3000 transceiver b/	19 to 34	194 dB_{RMS}	300	3	26.5
Sonardyne Scout Pro transponder b/	35 to 50	188 dB_{RMS}	300	1	42.5
Easytrak Nexus 2 USBL transceiver b/	18 to 32	192 dB_{RMS}	300	1	26
IxSea GAPS transponder b/	20 to 32	188 dB_{RMS}	20	10	26
Kongsberg HiPAP 501/502 USBL transceiver b/	21 to 31	190 dB_{RMS}	300	1	26
Edgetech BATS II transponder b/	17 to30	204 dB_{RMS}	300	3	23.5
Shallow Sub-Bottom Profiler (Chirp)					
Edgetech 3200 c/	2 to 16	212 dB_{RMS}	150	5	9
EdgeTech 216 b/	2 to 16	174 dB_{RMS}	22	2	6
EdgeTech 424 b/	4 to 24	176 dB_{RMS}	3.4	2	12
EdgeTech 512 b/	0.5 to 12	177 dB_{RMS}	2.2	2	3
Teledyne Benthos Chirp III - TTV 170 b/	2 to 7	197 dB_{RMS}	5 to 60	4	3.5
GeoPulse 5430 A Sub-bottom Profiler b/, e/	1.5 to 18	214 dB_{RMS}	25	10	4.5
PanGeo LF Chirp b/	2 to 6.5	195 dB_{RMS}	481.5	0.06	3
PanGeo HF Chirp b/	4.5 to 12.5	190 dB_{RMS}	481.5	0.06	5
Parametric Sub-Bottom Profiler					
Innomar SES-2000 Medium 100 c/	85 to 115	247 dB_{RMS}	0.07 to 2	40	85
Innomar SES-2000 Standard & Plus b/	85 to 115	236 dB_{RMS}	0.07 to 2	60	85
Innomar SES-2000 Medium 70 b/	60 to 80	241 dB_{RMS}	0.1 to 2.5	40	70
Innomar SES-2000 Quattro b/	85 to 115	245 dB_{RMS}	0.07 to 1	60	85
PanGeo 2i Parametric b/	90-115	239 dB_{RMS}	0.33	40	102
Medium Penetration Sub-Bottom Profiler (Sparker)					
GeoMarine Geo-Source 400J d/	0.2 to 5	212 dB_{Peak} 201 dB_{RMS}	55	2	2
GeoMarine Geo-Source 600J d/	0.2 to 5	215 dB_{Peak} 205 dB_{RMS}	55	2	2
GeoMarine Geo-Source 800J d/	0.2 to 5	215 dB_{Peak} 206 dB_{RMS}	55	2	2
Applied Acoustics Dura-Spark 400 System d/	0.3 to 1.2	225 dB_{Peak} 214 dB_{RMS}	1.1	0.4	1
GeoResources Sparker 800 System d/	0.05 to 5	215 dB_{Peak} 206 dB_{RMS}	55	2.5	1.9

Table 1 continued.

Representative HRG Survey Equipment	Range of Operating Frequencies (kHz)	Baseline Source Level a/	Representative RMS_{90} Pulse Duration (millisec)	Pulse Repetition Rate (Hz)	Primary Operating Frequency (kHz)
Medium Penetration Sub-Bottom Profiler (Boomer)					
Applied Acoustics S-Boom 1000J b/	0.250 to 8	228 dB_{Peak} 208 dB_{RMS}	0.6	3	0.6
Applied Acoustics S-Boom 700J b/	0.1 to 5	211 dB_{Peak} 205 dB_{RMS}	5	3	0.6

Notes:

a/ Baseline source levels were derived from manufacturer-reported source levels (SL) when available either in the manufacturer specification sheet or from the SSV report. When manufacturer specifications were unavailable or unclear, Crocker and Fratantonio (2016) SLs were utilized as the baseline:

b/ source level obtained from manufacturer specifications

c/ source level obtained from SSV-reported manufacturer SL

d/ source level obtained from Crocker and Fratantonio (2016)

e/ unclear from manufacturer specifications and SSV whether SL is reported in peak or rms; however, based on SLpk source level reported in SSV, assumption is SLrms is reported in specifications.

The transmit frequencies of sidescan and multibeam sonars for the 2019 marine site characterization surveys operate outside of marine mammal functional hearing frequency range.

It is important to note that neither Crocker and Farantino (2016), nor HRG manufacturer technical specifications report source levels in terms of the RMS_{90}, which is the metric required in assessment to the distance of NOAA Fisheries Level B harassment thresholds. Therefore, careful consideration should be made when attempting to make such direct comparisons. As shown in Crocker and Farantino, the pulse duration may also be a function of HRG operator settings.

Table 2. Summary of available information regarding the hearing sensitivities for fish species that are commonly encountered in the northwest Atlantic.

Species/Species Group	Family	Order	Sound Detection	Sensitivity
American eel	Anguillidae	Anguilliformes	Swim bladder close but not connecting to ear; Hearing by particle motion and pressure	Hawkins et al. 2020 Group 3 Up to 1-2 kHz
Alewife/herring/menhaden	Clupeidae	Clupeiformes (includes anchovies)	Weberian ossicles connecting swim bladder to ear; Hearing by particle motion and pressure	Hawkins et al. 2020 Group 4 Up to 3-4 kHz Alosinae detect to over 100 kHz
Cod/Pollock/Haddock/Hake	Gadidae	Gadiformes	Swim bladder close but not connecting to ear; Hearing by particle motion and pressure	Hawkins et al. 2020 Group 3 Up to 1-2 kHz
Mako sharks/mackerel sharks	Lamnidae	Lamniformes	No air bubble; Particle motion only	Hawkins et al. 2020 Group 1 Well below 1 kHz
Monkfish/goosefish	Lophiidae	Lophiiformes		unknown
Bluefish	Pomatomidae	Perciformes		unknown
Sea bass/groupers	Serranidae			unknown
Striped bass	Moronidae			unknown
Sand lance	Ammodytidae			unknown
Tautog	Labridae			unknown
Tunas/mackerels/albacores	Scombrinae		Swim bladder far from ear; Particle motion only	Hawkins et al. 2020 Group 2 Up to 1 kHz
Billfish/swordfish	Xiphiidae			unknown
Flounders/flatfish/sole/halibut	Pleuronectidae	Pleuronectiformes	No air bubble; Particle motion only	Hawkins et al. 2020 Group 1 Well below 1 kHz
Skates/rays	Rajidae	Rajiformes	No air bubble; Particle motion only	Hawkins et al. 2020 Group 1 Well below 1 kHz
Spiny dogfish	Squalidae	Squaliformes	No air bubble; Particle motion only	Hawkins et al. 2020 Group 1 Well below 1 kHz

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APPENDIX D
Power Analysis for Lobster and Crab Ventless Trap Survey

September 2020

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1.0 Introduction

For the ventless trap survey, a Before-After-Control-Impact (BACI) design is planned to sample lobsters, Jonah crabs and rock crabs within the SFWF Project Area and two selected reference areas. EXA conducted an assessment for South Fork Wind, LLC, including a power analysis for this survey.

For the ventless trap survey, the trap size/configuration and trawl layout will be identical to that used by the University of Rhode Island and the Commercial Fisheries Research Foundation in the Southern New England Cooperative Ventless Trap Survey (SNECVTS). The SNECVTS datasets from 2014 and 2015 (Collie and King 2016) were queried to assess the residual variance estimates of lobster, Jonah crab and rock crab catch for use in this power analysis. The relationship between effect size and statistical power for the specific BACI contrast of interest was estimated under several alternative hypotheses about declines in the impact area relative to the control areas, and two different design alternatives were considered (i.e., two or three years post-construction).

2.0 Data and Assumptions

The survey design employed in the SFWF area will utilize 10-trap trawls configured identical to the trawls used in the SNECVTS survey (Collie and King 2016). The SNECVTS survey sampled three times per month over 6 months (May – October) each year. The SFWF ventless trap survey will sample twice per month over 7 months (May – November). The SFWF survey design will have an equal number of trawls in each area (Project Area and two reference areas) each year, with trawl locations randomly set during the first sampling event of each year and held fixed throughout the year, so that the response variable is annual average catch per trawl.

Details about the SNECVTS design:

- Each SNECVTS trawl was comprised of 10 traps, with six ventless (V) and four vented (or standard, S) using the following pattern: V-S-V-S-V-V-S-V-S-V. The trawl layout for the SFWF survey will be identical.
- Aliquot = random station location where a 10-trap trawl was placed. Same location was fished throughout the year, and a new location was randomly selected the next year. Similar approach will be used in the SFWF survey.

Data summaries were derived from the SNECVTS database as follows:

- The Lobsters table was queried, and the total lobster catch per 10-trap trawl was tallied. The Lobsters table only recorded non-zero catch, so zero catch trawls were added to the analysis table for trawls that were present in the Trawls table and absent in the Lobsters table.
- The final catch is summarized as average catch (number of lobsters) per trap (averaged over both trap types). The SFWF survey will use the same trawl configuration as the SNECVTS survey. Results may easily be converted to average catch per 10-trap trawl by multiplying catch results by 10.
- Similar queries were done on the bycatch tables for each year to obtain estimates for the Jonah and rock crab catch.

In the SNECVTS study, there were 24 aliquots sampled per year across the entire RI/MA BOEM lease area; five of these aliquots were within the SFWF footprint. Variances were summarized for the entire BOEM lease area, and separately for the SFWF Project Area. Aliquot numbers associated with the SFWF Project Area by year were:

- 2014: 14, 15, 20, 21, 22
- 2015: 38, 39, 44, 45, 46

In the SNECVTS study, each aliquot was fished three times per month over 6 months. For this analysis, annual catch rates were divided by 18 to get an annualized average catch per trawl in each aliquot. The database did not have information on missing/compromised traps, so all trawls were assumed to have 10 traps and catch per trawl was divided by 10 to estimate the annual average catch per trap (CPUE). Mean and variability across aliquots were summarized for the entire lease area, and for the subset of aliquots present within the SFWF footprint (Table 1). The CPUE data followed a lognormal distribution both for the SNECVTS dataset and the BIWF ventless trap dataset (2013-2018), so the data are summarized both on original and natural log scale. The mean, standard deviation and coefficient of variation (CV = standard deviation / mean) are reported, as well as the residual standard error (RSE). The RSE is used in the power calculations.

Table 1. Summary of mean and standard deviation for average catch of lobster and crab per trap (averaged over both trap types) in the SNECVTS dataset.

			Lobster		Jonah Crab		Rock Crab	
Group	**Scale**	**Summary Statistic**	**2014**	**2015**	**2014**	**2015**	**2014**	**2015**
All (n=24)	Original Scale	Mean	2.49	2.10	7.29	4.91	3.57	4.34
		Std Dev	1.60	0.83	3.27	1.84	3.59	4.11
		CV	64%	40%	45%	37%	100%	95%
	Log-scale	Mean	0.75	0.67	1.90	1.51	0.94	1.28
		Std Dev	0.57	0.37	0.44	0.44	0.85	0.55
		CV	76%	56%	23%	29%	90%	43%
			RSE = 0.48		**RSE = 0.44**		**RSE = 0.72**	
SFWF (n=5)	Original Scale	Mean	1.45	1.75	9.53	4.83	2.10	3.53
		Std Dev	0.61	0.53	5.41	0.55	0.92	1.13
		CV	42%	30%	57%	11%	44%	32%
	Log-scale	Mean	0.3	0.51	2.12	1.57	0.66	1.23
		Std Dev	0.4	0.33	0.58	0.12	0.48	0.29
		CV	130%	66%	27%	8%	73%	23%
			RSE = 0.36		**RSE = 0.42**		**RSE = 0.39**	

The SFWF ventless trap survey is designed to sample twice per month for 7 months. Bootstrapping was used to estimate the RSE for a 2x per month survey design using the SNECVTS dataset. The temporal patterns of catch in both the SNECVTS and BIWF surveys indicated that peak abundance had not always passed as of October, so sampling through November should result in variance estimates that are less than the values estimated here. The bootstrap estimates from the SNECVTS database used the following approach:

- Sample two dates per month (without replacement) to reflect the design planned for SFWF and estimate an annual mean per trawl.
- Sample k=5 trawls (with replacement) for each year from the entire BOEM lease area (n=24) and from the SFWF area (n=5). Repeat for k=5, 6, 7, 8 trawls.
- Calculate the RSE from the bootstrapped dataset for the BOEM lease area and the SFWF Project Area.
- Repeat process 5000 times. Results are summarized in Table 2.

Table 2. Table of RSE from bootstrap resampling (R=5000) of results on entire BOEM lease area and SFWF Project Area, sampling 2 dates per month and drawing 5, 6, 7, or 8 trawls per year.

	BOEM lease area (n=24)			SFWF Project Area (n=5)		
	Percentile			Percentile		
Trawl Count	**50th**	**75th**	**90th**	**50th**	**75th**	**90th**
Lobsters						
5 Trawls	0.47	0.56	0.63	0.34	0.39	0.45
6 Trawls	0.48	0.55	0.61	0.34	0.39	0.44
7 Trawls	0.48	0.54	0.60	0.34	0.39	0.44
8 Trawls	0.48	0.54	0.59	0.34	0.39	0.43
Jonah crabs						
5 Trawls	0.43	0.51	0.57	0.38	0.44	0.49
6 Trawls	0.43	0.50	0.55	0.38	0.43	0.48
7 Trawls	0.43	0.49	0.54	0.38	0.42	0.47
8 Trawls	0.44	0.49	0.54	0.38	0.42	0.46
Rock crabs						
5 Trawls	0.68	0.84	0.98	0.36	0.41	0.45
6 Trawls	0.69	0.83	0.96	0.36	0.40	0.44
7 Trawls	0.70	0.83	0.95	0.36	0.40	0.43
8 Trawls	0.70	0.82	0.93	0.36	0.40	0.43

The results for the SFWF Project Area changed very little when the number of trawls increased from 5 to 8, likely due to the small sample size from which the estimates were bootstrapped (n=5). However, the results for the BOEM lease area suggest that more trawls should reduce the upper bound of the expected variance, with little effect on the median value. Conservative results for all three species in the SFWF Project Area indicate an RSE in the range of [0.34, 0.49].

3.0 Methods

A power analysis is specific not only to study design and statistical model, but the hypothesis within that model that we want to test. The interaction hypotheses of interest associated with the ventless trap survey are as follows:

- $H_Ø$: Changes in CPUE in both the control and impact sites will be identical over time
- H_1: Changes in CPUE will not be the same at the control and impact sites over time (two-tailed)

Consistent with the SNECVTS and BIWF ventless trap datasets, the SFWF CPUE data are expected to be lognormally distributed. Consequently, a standard ANOVA model with normal errors may be used which greatly simplifies the power calculations. The effect sizes and residual variability were expressed on the log-scale, and power was estimated using the function *pwr::pwr.f2.test* (Champely 2020) within R version 4.0.0 (R Core Team 2020).

The study design has 2 years nested within each time period (before/after), and 2 control sites and an impact site within treatment. The interaction contrast we wish to test is the difference between the temporal change at the windfarm and the temporal change at the control sites, or $\Delta = \delta_{SFWF} - \delta_C$ where:

> $\delta_{SFWF} = \mu_{SFWF,B} - \mu_{SFWF,A}$ is the temporal difference in means (two-year average from the "before" period minus two-year average from the operation period) at the SFWF site.
>
> $\delta_C = \mu_{C,B} - \mu_{C,A}$ is the temporal difference in means at the control sites (multiple control sites are averaged within each period)

As a linear contrast, this test of Δ has the following coefficients, c_{ij}: (0.5, 0.5, -0.5, -0.5, -0.25, -0.25, 0.25, 0.25, -0.25, -0.25, 0.25, 0.25) where *i* = 1 (SFWF), 2 (Control 1), or 3 (Control 3); and *j* = years 1 to 4. The effect size for this contrast is calculated as in Perugini et al (2018) using following formula:

$$f = \left|\sum c_{ij}\mu_{ij}\right| / \sqrt{k \sum c_{ij}^2 \sigma^2} \qquad \text{[Eq. 1]}$$

where μ_{ij} is the mean of log(CPUE) in the ith area and *j*th year, and σ is the residual standard error (RSE = standard deviation of annualized log(CPUE) among trawls within each area and year). The RSE for the trawls within the SFWF footprint (n=5 in each of 2 years) for lobsters and crabs had median and 90th percentiles within the range of 0.34 to 0.49 (Table 2). Therefore, the following four RSE values will be used to capture the range of expected variability in the annual mean CPUE for lobsters and crabs: 0.35, 0.40, 0.45, 0.50.

The interaction effect size was calculated for a pattern of response with the temporal shift at the SFWF being a proportion of the shift at the control sites. All else being equal, the effect size 'f' is the same whether SFWF decreases by 50% and control sites are unchanged, or SFWF doubles and control sites increase by factor of 4: the relative change at control to SFWF is still 2 to 1. The SNECVTS 2014-2015 average CPUEs were used as the baseline year averages in all 3 areas (SFWF and Control 1 and Control 2). Effect sizes were calculated for two different proportional changes:

- **Level 1** (a small to moderate delta): a multiplier of change of 3/2 at controls or 2/3 at wind farm (a relative delta of 0.67), e.g., for baseline wind farm catch of 2 lobsters/trap the catch would decrease by 1/3 to 1.33 lobsters/trap during operation, and controls would stay the same.

- **Level 2** (a large delta): a multiplier of change of 2/1 at controls or 1/2 at windfarm (a relative delta of 0.5), e.g., for baseline wind farm catch of 2 lobsters/trap the catch would decrease by 50% to 1 lobster/trap during operation, and catches at the control sites would stay the same.

- The same effect size could be achieved with both the RSE and % change at windfarm either increasing or decreasing. For example, an interaction effect size of 0.27 could be achieved with all of the following combinations: (RSE =0.45, 40% decrease at windfarm), (RSE=0.35, 33% decrease), and (RSE=0.25, 25% decrease).

A spatially asymmetrical design is assumed with a single impact site and two control sites. Two different temporal scales are tested: two years of monitoring before construction contrasted with either two or three years of monitoring after construction.

Table 3. Interaction effect sizes calculated for BACI contrast (using Equation 1) for two different levels of change and range of likely RSE values

RSE	Change Level 1 Relative Delta = 0.67	Change Level 2 Relative Delta = 0.5
Two years before; Two years after		
0.35	0.27	0.47
0.40	0.24	0.41
0.45	0.21	0.36
0.50	0.19	0.33
Two years before; Three years after		
0.35	0.26	0.46
0.40	0.23	0.40
0.45	0.21	0.36
0.50	0.18	0.32

4.0 Results

Power was calculated as a function of sample size, for the range of interaction effect sizes shown in Table 3 for a design with one impact area and two control areas for 2 years before construction, and either 2 years (Figure 1) or 3 years (Figure 2) after operation. The minimum sample sizes to achieve 80% power with 90% confidence for the specific interaction effect sizes are presented in Table 4.

Table 4. Minimum sample sizes (power= 80%, confidence = 90%) for select interaction effect sizes

Interaction Effect Size	No. of Years in Operation Period		Assumptions
	2 years	3 years	
0.19	16	13	Small-moderate delta; high RSE
0.24	10	9	Small-moderate delta; moderately high RSE
0.27	9	7	Small-moderate delta; median RSE
0.33	6	5	Large delta; high RSE
0.41	5	4	Large delta; moderately high RSE
0.47	4	3	Large delta; median RSE

Notes:
Small-moderate delta is a 33% decrease at the windfarm with no change at control sites; a large delta is a 50% decrease at windfarm with no change at controls. The same effect size could be achieved if both delta and RSE decreased or increased.
RSE = residual standard error

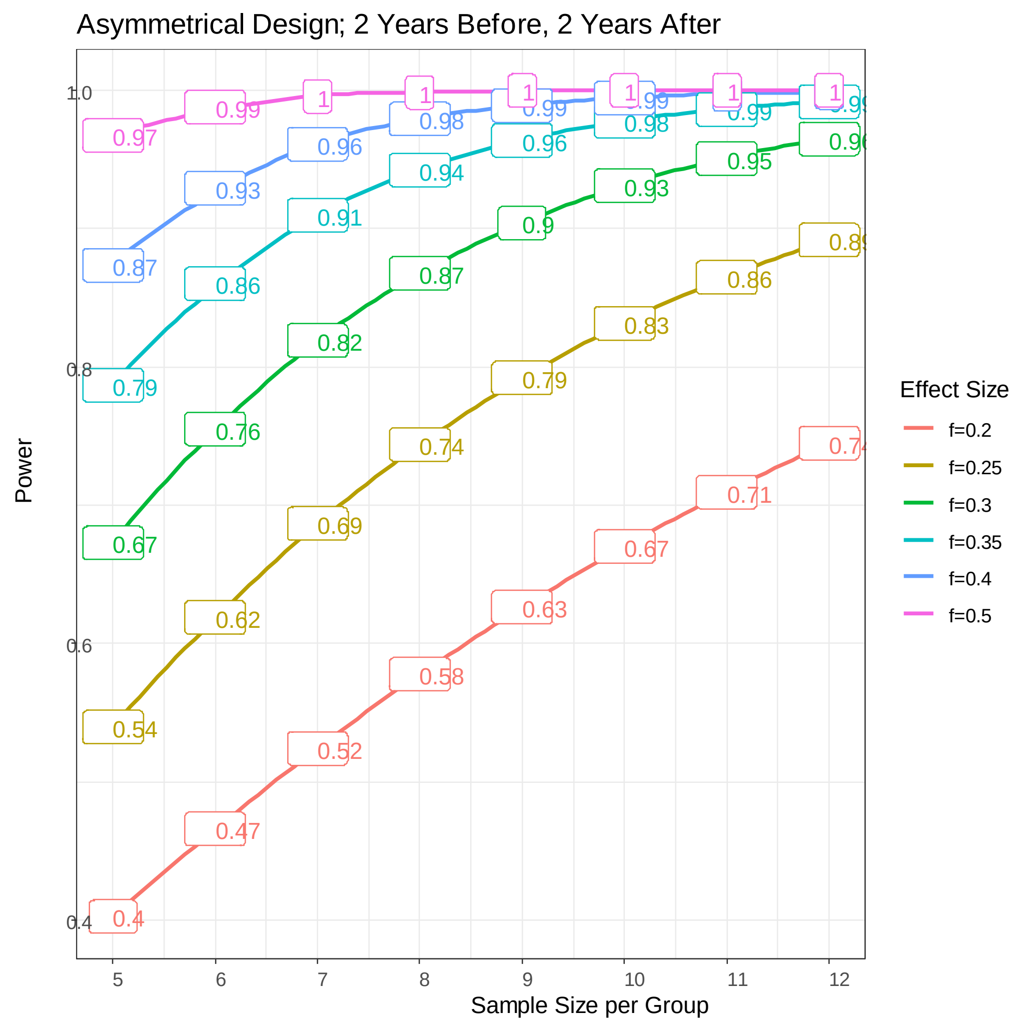

Figure 1. Power versus sample size (number of trawls) per area-year group for a range of interaction effect sizes (see Table 3), using a study design with single impact and two control areas for 2 years before and 2 years after construction, and α= 0.10.

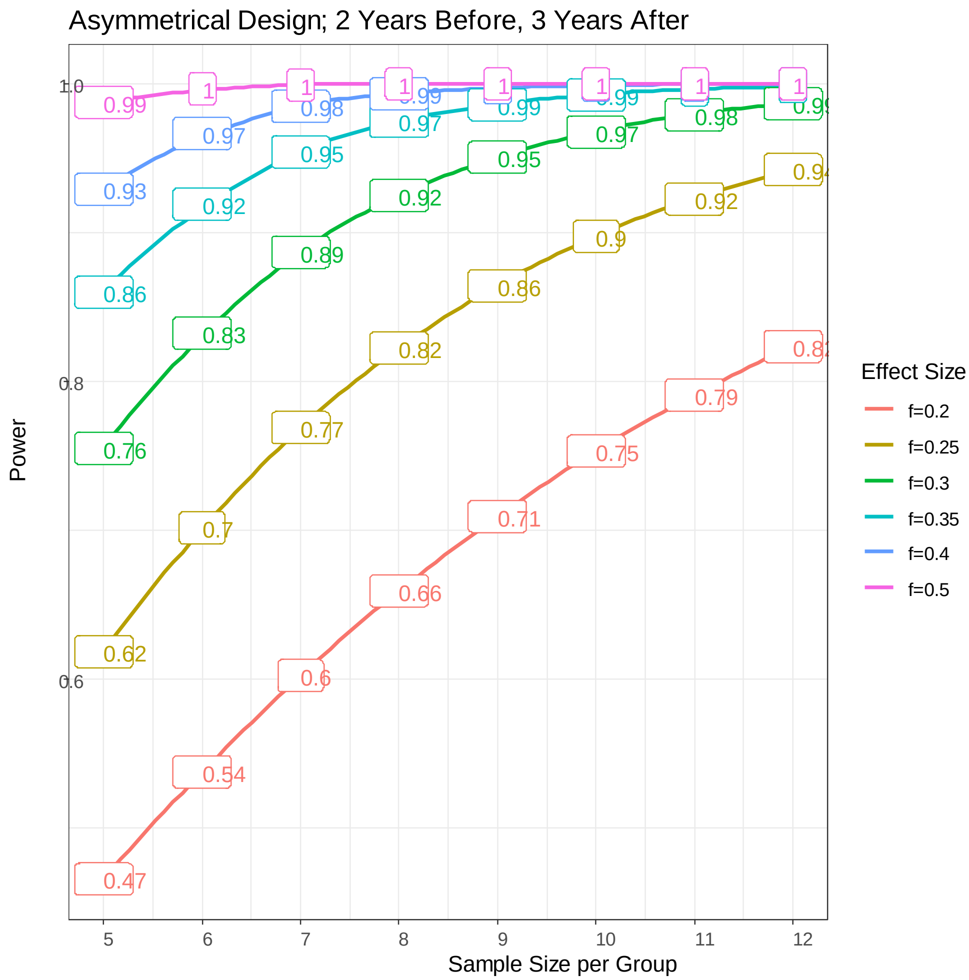

Figure 2. Power versus sample size (number of trawls) per area-year group for a range of interaction effect sizes (see Table 3), using study design with single impact and two control areas for 2 years before and 3 years after construction, and α= 0.10.

5.0 References

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